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AN EXPLORATION INTO DIFFERENCES BETWEEN THE LEARNING OF VARIOUS AGE GROUPS WAS CONDUCTED TO OBTAIN DATA OF DEVELOPMENTAL PROCESSES FOR THE FORMATION OF LEARNING SET. THE OBJECT-QUALITY DISCRIMINATION LEARNING SET WAS STUDIED TO SEARCH FOR SYSTEMATIC RESPONSE PATTERNS, AND TO EXAMINE AGE DIFFERENCES. THE SAMPLES USED IN THIS STUDY WERE 53 NURSERY SCHOOL CHILDREN, 53 FIFTH GRADERS, 57 COLLEGE FRESHMEN, AND 209 AGED PEOPLE. EACH WAS GIVEN PRACTICE ON NUMEROUS TWO-STIMULI PROBLEMS. COMPARISONS ACROSS AGE LEVELS WERE CONDUCTED AND AN AGE TREND IN RATE OF SET ACQUISITION OBTAINED. (RS)

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**PATTERNS OF DISCRIMINATION LEARNING SET
IN PRESCHOOL CHILDREN, FIFTH GRADERS,
COLLEGE FRESHMEN, AND THE AGED**

Cooperative Research Project No. 1059

Billey Levinson and Hayne W. Reese

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State University of New York at Buffalo
1963

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Chapter 1

Introduction

The development of "learning set" or "learning how to learn" has been termed "interproblem learning" and is a special case of transfer of training (Harlow, 1949; 1959). The learning set procedure provides measures of learning efficiency not only within a single discrimination problem, but also as a cumulative improvement across large numbers of problems. Learning set experiments have provided information that goes much beyond the data supplied by studies of simple discrimination learning, and hence may materially advance our understanding of the nature of learning.

A newly developed method of analyzing learning set data makes possible the exploration of the processes which occur during the achievement of the correct solution. The processes involved in the mastery of learning set appear to require certain abilities which may be in the early stages of development in young children, well developed in older subjects (Ss), and deteriorating in aged Ss with the onset of senility. Therefore, in exploring differences between the learning of various age groups, data are obtained which may be not only of developmental significance but also of importance for the understanding of the processes which lead to the formation of learning set.

A survey of the literature on learning set in animals and humans reveals a substantial accumulation of information on each of the groups studied, despite the utilization of a wide variety of procedures and techniques. In that the learning set method may be applied with similar procedure to both animal and human Ss as well as to Ss of all ages, valid comparisons of complex learning performances are feasible on the phylogenetic and ontogenetic scales.

In learning set experiments, a different pair of stimulus objects is used for each problem, and the S is given new problems until a criterion of success is met. In each discrimination problem, one object is correct, the position of the correct object is shifted to the right or left in a randomly determined order, and a correct choice is rewarded. As learning set develops, it is accompanied by an increase in correct responses. As a result of the formation of learning set, changes in S's learning efficiency occur, so that the solution of a new problem is immediate; and whether S succeeds or fails on the first trial, he invariably gains information indicating the correct solution.

Because of the difficulties in controlling previous learning history of human Ss, most of the studies in which the learning set variables have been explored used rhesus monkeys as Ss. The acquisition of discrimination learning set has also been studied in other primate species (Harlow, 1959; Hayes, Thompson, & Hayes, 1953; Miles, 1957; Miles & Meyer, 1956; Shell & Riopelle, 1958) and in some lower animals such as cats (Meyers, McQuiston, & Miles, 1962; Warren, 1959; 1960; Warren & Baron 1956; Warren & Kimball, 1959), raccoons (Johnson & Michels, 1958; Michels, Pustek, & Johnson, 1961; Shell & Riopelle, 1957), rats (Koronakos & Arnold, 1957), and pigeons (Zeigler, 1961).

These studies have shown that the acquisition of learning set is related to both phylogenetic and ontogenetic development. In phylogenetic comparisons, studies of learning set development in various species have indicated that the species are ordered in their performance, and furthermore that the ordering based on this behavioral measure corresponds with that based on taxonomy. The learning set situation appears to be one of the few learning problems with which it is possible to differentiate among species even within the primate order (Zeigler, 1961).

Other studies have compared the performance of normal and brain-damaged Ss and reported that these groups exhibit quantitative differences in the formation of learning sets (Harlow, Meyer, & Settlage, 1951; Wischner, Braun, & Patton, 1961). Animals with frontal lobe lesions have been shown to be inefficient in developing learning sets because of particular difficulty in overcoming spontaneous object preferences and aversions (Brush, Mishkin, & Rosvold, 1961). It has been suggested that animals with large neocortical resections solve single discrimination problems without deficit, but fail to acquire learning set (Chow, 1954; Riopelle, Alper, Strong, & Ades, 1953).

Only a few studies have explored age as a variable in learning set formation. Harlow, Harlow, Rueping, & Mason (1960) have demonstrated that the ability of infant monkeys to solve individual discrimination problems occurs far earlier than the ability to form discrimination learning sets. Even the year-old monkey, which in other respects matures rapidly, is not the equal of the adult monkey in its efficiency of learning set formation.

The discrimination learning set procedure was first applied to human Ss by Kuenne (1949), who found a relationship between intelligence and learning set performance in preschool children. Studies have been reported on samples of nursery school children (Hayes, Thompson, & Hayes, 1953; Koch & Meyer, 1959; Shepard, 1957; Stevenson & Swartz, 1958), retarded children (Bowes & Wischner, 1959; de Haan & Wischner, 1960; Girardeau, 1959; House & Zeaman, 1958; Kaufman & Peterson, 1958; Wischner, Braun, & Patton, 1958; Wischner & O'Donnell, 1961), normal adults (Adams, 1954; Morrisett & Hovland, 1959), and adult defectives (Ellis, 1958). (See review by Reese, 1963.)

These studies of learning set in human Ss have employed so many procedural variations that it is apparent that a need existed for a single study of

discrimination learning set in human Ss at several age levels. The procedure adopted in the present study consisted of the presentation of a fixed number of trials per problem. This procedure permitted an analysis of the response patterns during the course of learning set acquisition (Moon & Harlow, 1955), and should prove fruitful in exploring differences between various age groups. It appears appropriate that the knowledge obtained from studies on infra-human primates should be applied to the evaluation of human learning abilities.

The traditional measure of progress in learning set experiments has been the change in the percentage of correct responses in a series of problem-blocks. The search for systematic response patterns, "hypotheses" (Krechevsky, 1932), is an alternative means of analysis. In such an approach four types of orderly, but inappropriate, response sequences or "error factors" have been identified (Harlow, 1950). Similar categorizing of behavior has been described in probability-matching where animal and human Ss, presented with a random two-choice sequence, develop patterns of responding or hypotheses. Such patterns were termed "strategies" (Brunner, Goodnow, & Austin, 1956; Goodnow & Pettigrew, 1955), and have been described in two-choice gambling games (Goodnow, 1955; Goodnow & Postman, 1955), risk-taking behavior (Atkinson, 1956; 1957; Atkinson & Suppes, 1958), and decision making (Edwards, 1953; 1954).

The learning set procedure differs from that of probability-matching, gambling games, etc., in that the trials are organized into sequences (problems) with a definite beginning, and duration, and in that there is a pattern which is the correct solution. According to learning set theory (Harlow & Hicks, 1957), different error-producing factors determine responses during various segments of the learning process. As each of these error sources is eliminated, the probability of occurrence of the correct response increases; when the correct response

occurs consistently, learning is said to have occurred. Thus, discrimination learning set may be viewed as a result of the inhibition of incorrect behaviors, or error-factor elimination.

The error factors described by Harlow (1950) are: Stimulus Perseveration, the repetitive choice of the incorrect object; Position Habit, consistent responses to either the right or left position, regardless of the position of the correct object; Response Shift, a shift to the incorrect stimulus following one or more correct responses; and Differential Cue, an error on the trial subsequent to a shift of the rewarded position, presumably because S responds to the previously rewarded position rather than to the previously rewarded object. The study of error factors has led to a considerable accumulation of information, particularly in monkey learning (Harlow, 1959), and has also been applied to the data of mentally retarded children (House & Zeaman, 1958; Kaufman & Peterson, 1958) and preschool children (Hill, 1961).

A model of error analysis developed by Levine (1959) permits the simultaneous analysis of a large number of response patterns (hypotheses). The symbol H represents a specifiable pattern of responses; and there are a number of incorrect Hs as well as a correct H, the problem solution. This model provides individual estimates of the relative strengths of response patterns at each stage during learning, and has been applied to position reversal learning in the rat (Pubols, 1961), discrimination learning set (Levine, 1959) and object-alternation learning in monkeys (Behar, 1961), probability-matching in Chimpanzees and children (Schusterman, 1961), and single-problem learning in children (Hill, 1961).

A modification of the H-model draws data only from the first two trials of each problem (Levine, 1963). Any response on Trial 1 can be correct only by

chance. "Win" designates a correct Trial 1, and "lose", an incorrect Trial 1. There are two response alternatives on Trial 2: S may shift his response or he may perseverate ("stay"). A response is determined either by stimulus object or by stimulus position referents. There are eight possible combinations of "win" and "lose" responses, termed Hs, which are organized into complementary pairs (see Table 1-1). The Levine equations (given in Appendix A) yield a relative solution (differential score), which is the amount by which the proportion of responses resulting from one of a complementary pair of Hs exceeds the proportion of responses accounted for by the alternative H. The differential scores range from -1.00 to +1.00, the former indicating that an even-numbered H (Table 1-1) is dominant, and the latter that an odd-numbered H is dominant. A zero suggests that the complementary Hs are equally effective (or that both are absent).

A recent extension of the H-model (Bowman, 1963) allows for limits to be established for each pattern of response, treating separately the "win" and the "lose" responses. Each H thus contains two components which are termed "strategies." Applying Bowman's notations (Table 1-1), the response following a win may be attributed to one of the following strategies: Win-stay, with respect to objects (WSt_o); Win-shift, with respect to objects (WSh_o); Win-stay, with respect to position (WSt_p); and Win-shift, with respect to position (WSh_p). The corresponding strategies following a lose are symbolized by LSt_o , LSh_o , LSt_p , and LSh_p , respectively. The proportion (or percentage) of the responses controlled by each of these strategies can be estimated as lying within certain limits; the proportion of responses by which one strategy exceeds its complement (WSt_o vs. WSh_o , WSt_p vs. WSh_p , LSt_o vs. LSh_o , and LSt_p vs. LSh_p) may be calculated exactly, and is equal to the difference between the upper limits of the two strategies (see Appendix A).

Table I - I

Definitions and Symbols of the Response Sequences in a Two-Trial Model¹

Differential Symbol	Description	Name	Bowman's Symbols
D _a	H ₁ : S stays on the same object after a win and shifts after a loss.	Win-stay, lose-shift, with respect to object.	WSt _O & LSh _O
	H ₂ : S shifts to the alternate object after a win, and stays after a loss.	Win-shift, lose-stay with respect to object.	WSh _O & LSt _O
D _b	H ₃ : S stays on the same position after a win, and shifts after a loss.	Win-stay, lose-shift, with respect to position.	WSt _P & LSh _P
	H ₄ : S shifts position after a win and stays after a loss.	Win-shift, lose-stay, with respect to position	WSh _P & LSt _P
D _x	H ₅ : S stays on the same object each trial.	Stimulus preference.	WSt _O & LSt _O
	H ₆ : S shifts object selected.	Stimulus alternation.	WSh _O & LSh _O
D _y	H ₇ : S stays on the same position each trial.	Position preference (Position habit)	WSt _P & LSt _P
	H ₈ : S shifts position on each trial.	Position Alternation.	WSh _P & LSh _P

¹Adapted from Levine (1963) and Bowman (1963): H₅ - H₈ result from response sets which ignore the consequences of Trial 1.

The Hs and the strategies describe rather than explain the response sequences. That is, the statement, "The Ss used the LSh₀ strategy," means that the Ss exhibited the LSh₀ response pattern and does not imply that the Ss applied verbal self-instruction which led to the observed behavior.

The studies here reported sampled four age ranges widely separated on the age continuum. The Ss were from nursery school, fifth grade, college freshman, and aged groups. Although these age groups were selected to maximize expected age differences in the rate of acquisition of learning set, it should be noted that each group presents unique educational problems, and could have been selected with equal validity on that basis. The formation of the learning set in each of the samples was analyzed by examination of the course of the hypotheses derived from Levine's two-trial model and the strategies calculated by use of Bowman's equations.

Chapter 2

General Methodology

Apparatus. The apparatus was a portable modification of the Wisconsin General Testing Apparatus (see Fig. 2-1). It consisted of a tray on which the stimulus objects were presented, and an opaque screen fixed to the S's side of the tray. The screen could be lowered to conceal the tray from the S between trials. Two $\frac{1}{4}$ -in. deep wells were centered on the tray to receive the reward; the wells were padded and during the trial were covered by the stimulus objects.

The stimuli consisted of a collection of 1000 laboratory fabricated and "junk" stereometric objects differing in multiple respects, e.g., shape, size, color, and complexity. They were organized into 500 pairs by the use of random numbers so that there was no systematic relationship between objects within pairs or between pairs. One object of each pair was randomly assigned as the "correct" object and was identified by a code mark on its base.

Procedure. The Ss were tested individually, with the apparatus placed on a table between S and the experimenter (E). Several Es worked simultaneously, using identical apparatus and instructions. An S was tested by only one E, as far as possible, and was assigned to a given E in a random fashion. The use of highly trained Es, who were required to make frequent checks of each other's procedures, minimized possible differences among Es.

Each pair of stimuli was used in a different problem, that is, each problem involved one of the pairs of stimulus objects. Four trials on each problem were given, each trial beginning with the raising of the screen, presenting to the S's view the two stimuli on the tray. The reward-well under the correct stimulus contained the reward. A non-correctional procedure was used, and the trial was

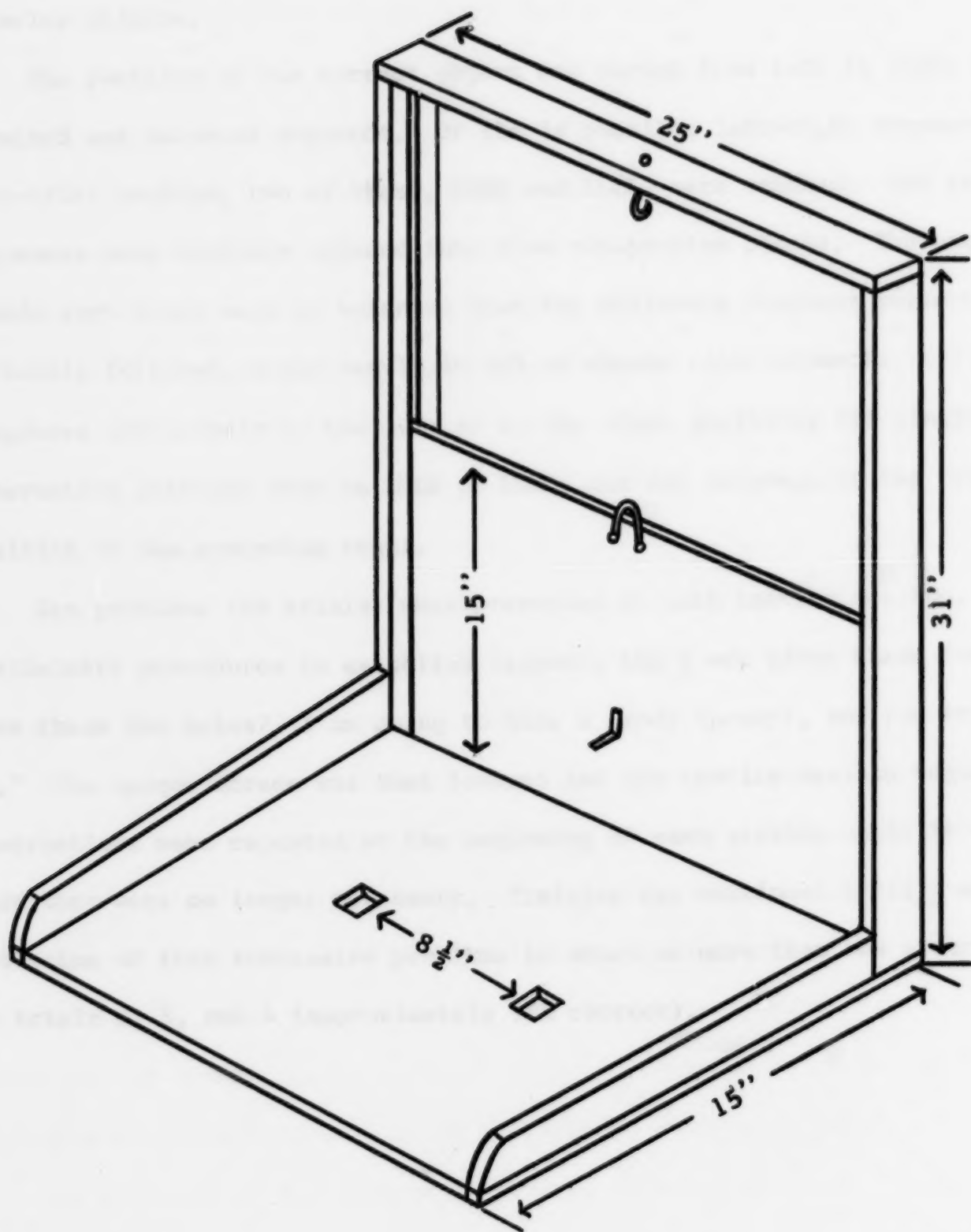


Fig. 2 - 1 Modification of the Wisconsin General Test Apparatus

terminated by the lowering of the opaque screen after S had displaced one of the stimulus objects.

The position of the correct object was varied from left to right in a predetermined and balanced sequence. Of the 16 possible left-right sequences for a four-trial problem, two of these, RRRR and LLLL, were omitted. The remaining sequences were randomly ordered into five ten-problem blocks. The sequences within each block were so balanced that the following response patterns, if consistently followed, would result in 50% or chance reinforcement: (a) all responses exclusively to the left or to the right position; (b) single or double alternation patterns such as LRLR or LLRR; and (c) response to the rewarded position of the preceding trial.

Ten problems (40 trials) were presented at each testing session. Following preliminary procedures to establish rapport, the S was given these instructions: "See these two holes? I am going to hide a candy (penny), and you try to find it." The opaque screen was then lowered and the testing session began. These instructions were repeated at the beginning of each session until it was obvious that they were no longer necessary. Training was continued until S achieved a criterion of five successive problems in which no more than one error was made on trials 2, 3, and 4 (approximately 93% correct).

Chapter 3

Discrimination Learning Set in Preschool Children¹

Although there has been considerable research on learning set in children, most of the studies have involved mental defectives as Ss (Ellis, 1958; House & Zeaman, 1958), with small groups of normal children included as controls (Girardeau, 1959; Kaufman & Peterson, 1958; Stevenson & Swartz, 1958). Learning set studies of normal preschool children have applied a wide variety of training procedures such as training to criterion on each problem (Girardeau, 1959; Stevenson & Swartz, 1958), training to criterion on early problems (Hayes, Thompson, & Hayes, 1953; Kuenne, 1949), or presenting a small number of problems (Shepard, 1957). Only one study (Koch & Meyer, 1959) has employed a fixed number of trials per problem until a criterion was reached, and an extensive collection of randomly assorted stimuli.

The evidence for normal children in the preschool range regarding the relationship between age and rate of acquisition of learning set is not clear. Several studies present data for preschool children as a group, but not for subgroups of different ages (Girardeau, 1959; Koch & Meyer, 1959; Kuenne, 1949; Shepard, 1957). The evidence on the correlation between rate of learning set formation and mental age is somewhat clearer, Koch and Meyer having obtained a significant correlation of $-.59$ in children from 29 to 66 months of age.

The purposes of the present experiment were (a) to study the rate of the acquisition of object-quality discrimination learning set in normal preschool

¹Papers reporting part of the data were presented at Midwestern Psychological Association, Chicago, May, 1961, and Eastern Psychological Association, Atlantic City, April, 1962.

groups, (b) to determine whether acquisition rate varies as a function of age within the preschool group, and (c) to trace the course of the response patterns occurring during the formation of learning set by use of Harlow's 1950 error factor analysis, and by applying the Levine and Bowman equations.

Method

Subjects. The entire populations of three all-day nursery schools¹ were tested, but some Ss were lost through fluctuations in attendance and a few through failure to cooperate. The total number of Ss carried to criterion was 53. These Ss ranged in CA from 36 to 66 months with a median CA of 52 months.

Apparatus. The apparatus and stimuli were identical to those described in Chapter 2.

Procedure. The Es spent several days at each of the nursery schools getting acquainted with the children and playing with them, so that rapport was established with each child before the testing began. The testing was conducted in unused rooms at the nursery schools. Testing began at each of these schools on a Monday and was continued daily except Saturday and Sunday until all of the Ss had reached criterion.

The rewards were "M & M" varicolored chocolate candies, which were of an appropriate size to fit easily into the food-wells. No S refused these. The Ss were given the preliminary instructions (see Chapter 2) and after their first correct choice, were encouraged to remove the candy from the food-well and eat

¹The writers gratefully acknowledge the cooperation and helpful assistance of the directors and staffs of the Delaware Child's nursery, the Guardian Angel Day Nursery, and the Jewish Center Nursery, of Buffalo, New York.

it; small paper cups were available for those who preferred to save some of the candy. The session was terminated, after the testing was completed, with a request to the child to avoid discussing the proceedings with other children. This warning was repeated at the end of each session.

Results

Acquisition Curves

The relationship between CA and days to criterion was weak and non-significant. A comparison of the mean number of days to criterion of Ss below the median CA with the mean of those above the median indicated that the age effect was non-significant (Mean difference = 1.19 days; $t < 1.00$). The Pearson product-moment correlation between CA and days to criterion was .085 ($t < 1.00$).

The commonly used method for analyzing the acquisition of learning set is to present Trial 2 data as a function of training on successive blocks of problems, or to combine Trial 2, 3, and 4 data. The latter procedure has the advantage of yielding more stable curves for small groups of Ss. Fig. 3-1 presents the data in both of these forms. For the construction of these curves, it was assumed that after S reached criterion all responses would be correct. It may be observed that the shape of the learning curve followed the typical negatively accelerated form reported in learning set studies for infra-human primates (Harlow, 1959, p. 497-498), and that in most cases there was a slightly greater percentage correct on the combined Trials 2, 3, and 4 than on Trial 2.

The difference between the corresponding data points of Trial 2 and combined Trials 2, 3, 4 is related to the amount of within-problem learning. To test the significance of within-problem learning, the total number of correct responses on Trial 2 was subtracted from the total correct on Trial 4. The mean increase for each S in number of correct responses from Trial 2 to Trial 4 for each

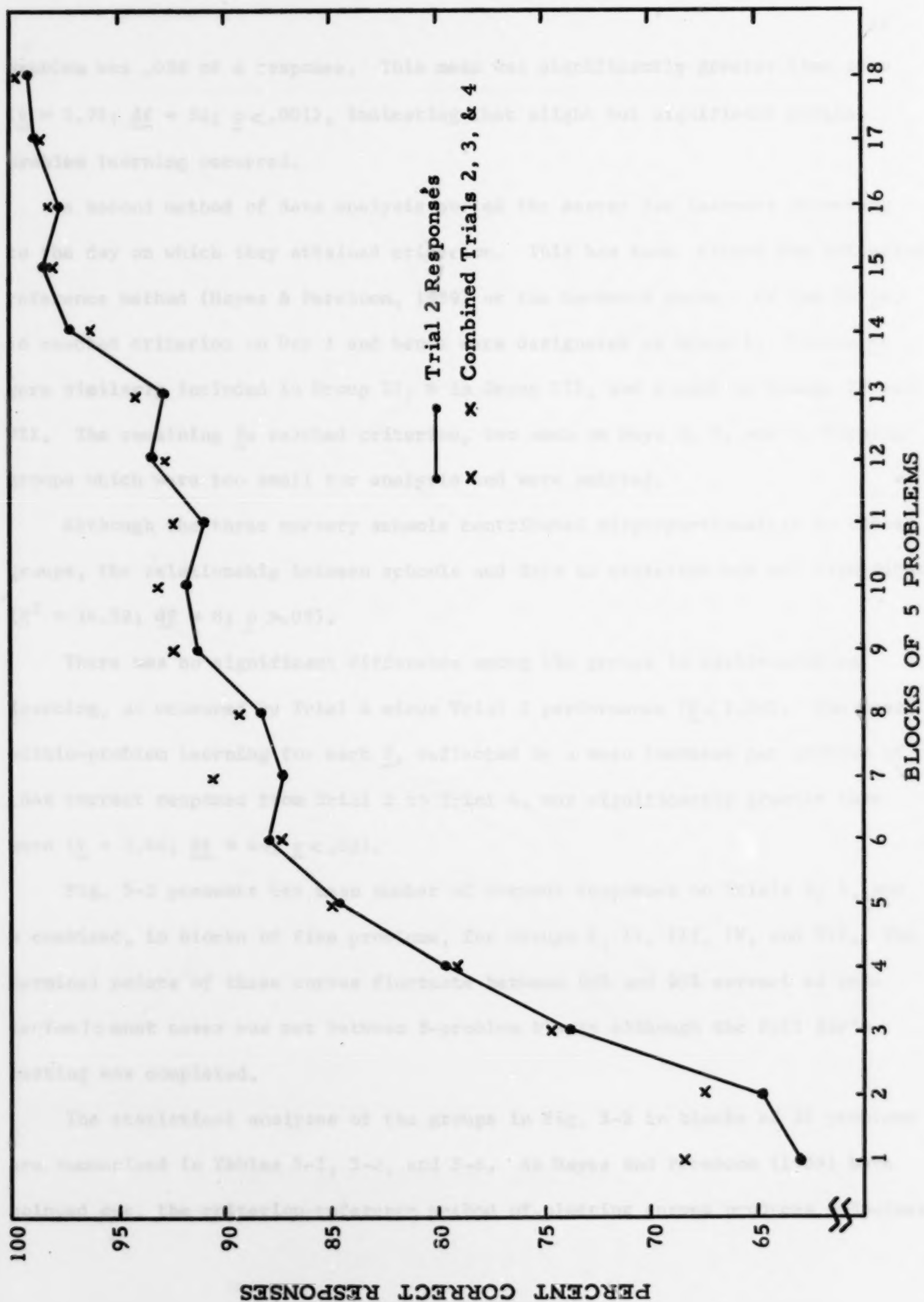


Fig. 3 - 1 Learning Set in Preschool Children

problem was .056 of a response. This mean was significantly greater than zero ($t = 3.73$; $df = 52$; $p < .001$), indicating that slight but significant within-problem learning occurred.

A second method of data analysis pooled the scores for learners according to the day on which they attained criterion. This has been termed the criterion reference method (Hayes & Pereboom, 1959) or the backward curve. Of the 53 Ss, 16 reached criterion on Day 1 and hence were designated as Group I. Eleven Ss were similarly included in Group II, 8 in Group III, and 6 each in Groups IV and VII. The remaining Ss reached criterion, two each on Days 6, 8, and 9, forming groups which were too small for analysis and were omitted.

Although the three nursery schools contributed disproportionately to these groups, the relationship between schools and days to criterion was not significant ($\chi^2 = 14.32$; $df = 8$; $p > .05$).

There was no significant difference among the groups in within-problem learning, as measured by Trial 4 minus Trial 2 performance ($F < 1.00$). The mean within-problem learning for each S, reflected by a mean increase per problem of .046 correct response from Trial 2 to Trial 4, was significantly greater than zero ($t = 2.46$; $df = 46$; $p < .02$).

Fig. 3-2 presents the mean number of correct responses on Trials 2, 3, and 4 combined, in blocks of five problems, for Groups I, II, III, IV, and VII. The terminal points of these curves fluctuate between 90% and 95% correct as criterion in most cases was met between 5-problem blocks although the full day's testing was completed.

The statistical analyses of the groups in Fig. 3-2 in blocks of 10 problems are summarized in Tables 3-1, 3-2, and 3-3. As Hayes and Pereboom (1959) have pointed out, the criterion-reference method of plotting curves produces endpoints

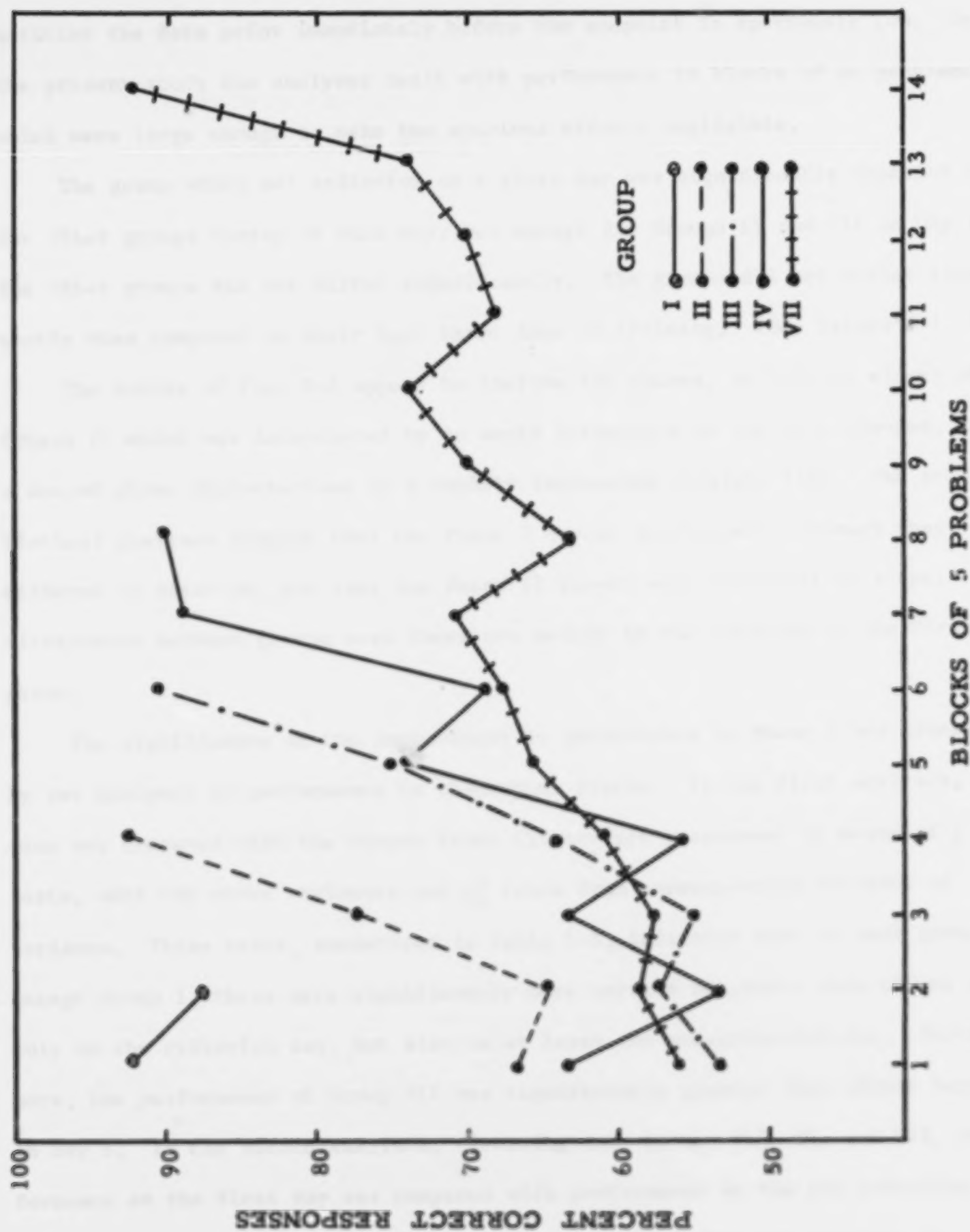


Fig. 3 - 2 Learning Set in Preschool Children (Combined Trials 2, 3, & 4)

which are spuriously high because they all include the criterion trials. In addition the data point immediately before the endpoint is spuriously low. In the present study the analyses dealt with performance in blocks of 10 problems, which were large enough to make the spurious effects negligible.

The group which met criterion on a given day was significantly superior to the other groups tested on that day; but except for Groups II and III on Day 1, the other groups did not differ significantly. The groups did not differ significantly when compared on their last three days of training. (See Tables 3-1, 3-2.)

The curves of Fig. 3-2 appear to include two phases, an initial slower phase (Phase I) which was interrupted by an acute inflection as the rate changed, and a second phase characterized by a rapidly increasing straight line. The statistical analyses suggest that the Phase I curves overlapped, although they differed in duration, and that the Phase II curves were identical in slope. The differences between groups were therefore mainly in the duration of the first phase.

The significance of the improvement in performance in Phase I was assessed by two analyses of performance in 10-problem blocks. In the first analysis, each mean was compared with the chance level (15 correct responses) by means of t tests, with the error variances and df taken from corresponding analyses of variance. These tests, summarized in Table 3-3, indicated that in each group, except Group I, there were significantly more correct responses than chance not only on the criterion day, but also on at least one pre-criterion day. Furthermore, the performance of Group VII was significantly greater than chance beginning on Day 3. In the second analysis, involving only Groups III, IV, and VII, performance on the first day was compared with performance on the day preceding the criterion day. An analysis of variance indicated that the increase in

Table 3-1

Summary of Analyses of Variance of Percentage Correct
Responses in Blocks of Ten Problems (Days)

Day	Between Groups		Within Cells		F	p
	df	ms	df	ms		
1	4	222.77	42	8.22	27.10	.001
2	3	146.79	27	11.73	12.51	.001
3	2	44.21	17	5.43	8.14	.005
4	1	133.33	10	9.37	14.23	.005
criterion-2 ^b	2	41.88	17	13.47	3.11	ns
criterion-1	3	17.18	27	10.44	1.64	ns
criterion ^a	4	9.23	42	6.57	1.40	ns

a. Criterion day for all groups.

b. Two days before criterion day.

Table 3-2

t Tests of Differences Between Groups in Percentage
Correct Responses in Blocks of Ten Problems (Days)

Groups Compared	Days			
	1	2	3	4
I & II	6.49**			
I & III	8.16**			
I & IV	6.93**			
I & VII	7.18**			
II & III	2.14*	4.94**		
II & IV	1.53	4.54**		
II & VII	1.75	4.54**		
III & IV	<1.00	<1.00	2.68*	
III & VII	<1.00	<1.00	3.87**	
IV & VII	<1.00	<1.00	1.12	3.77**

Note.--The error terms and df were derived from the appropriate within-cells ms of Table 3-1.

*_p < .05
**_p < .01

Table 3-3

t Tests of Differences between Mean Number Correct
and Chance in Blocks of Ten Problems

Group	Days (10-Problem Blocks)						
	1	2	3	4	5	6	7
I	16.67***						
II	5.50***	10.42***					
III	2.86	2.38*	12.05***				
IV	2.14*	2.02	6.84***	9.46***			
VII	1.85	2.02	5.26***	4.14**	6.01**	4.03**	8.70***

Note.--The error variances and df were taken from analyses of variance, except for the last three days of Group VII, on which they were computed directly.

All obtained means were greater than 15, which was the chance number of correct responses.

* $p < .05$
 ** $p < .01$
 *** $p < .001$

Table 3-4

Parabolic Correlation Coefficients (R_p)

Group	R_p	<u>F</u>	<u>df</u>	<u>p</u>
III	.982	40.87	2,3	< .01
IV	.911	12.18	2,5	< .025
VII	.854	14.84	2,11	< .001

performance was significant ($F = 7.00$; $df = 1, 17$; $p < .025$), and neither the Groups effect nor the Groups by Days interaction was significant ($F = 1.3$., $F < 1.00$, respectively).

Applying a least-squares solution, parabolic equations were fit to the total percentages correct responses in blocks of five problems for Groups III, IV, and VII. Table 3-4 gives the parabolic correlation coefficients, reflecting the accuracy of prediction with the parabolic equations. Since the parabolic equations yielded significantly accurate predictions, the percentage correct responses as a function of blocks of problems may be a parabolic function.

Error Factor Analyses

Differential Cue. Fig. 3-3 presents the percentage correct responses on Trial 2 as a function of (A) shift in stimulus position from Trial 1 to Trial 2; and (B), non-shift, the position of the two stimuli remaining the same for both of these trials. It is evident that all groups of Ss made more errors during the stimulus shift condition; seventeen comparable points in Fig. 3-3 yielded only two instances where the reverse was true.

In condition B, the choice of the previously rewarded object and the choice of the previously rewarded position are identical, and hence a selection on either basis is reinforced. In A these two possibilities result in different object choices, and only the selection of the previously rewarded object is reinforced. The amount of the difference in percentage correct responses between comparable points in A and B yields a conservative estimate of the strength of position responses. Harlow (1950) has identified Condition B as "multiple cue" trials, in view of the ambiguity of reward; and Condition A as "differential cue" trials.

In Fig. 3-3 it will be noted that performance improved as a function of practice in all groups, but that the endpoints in A relative to those in B were

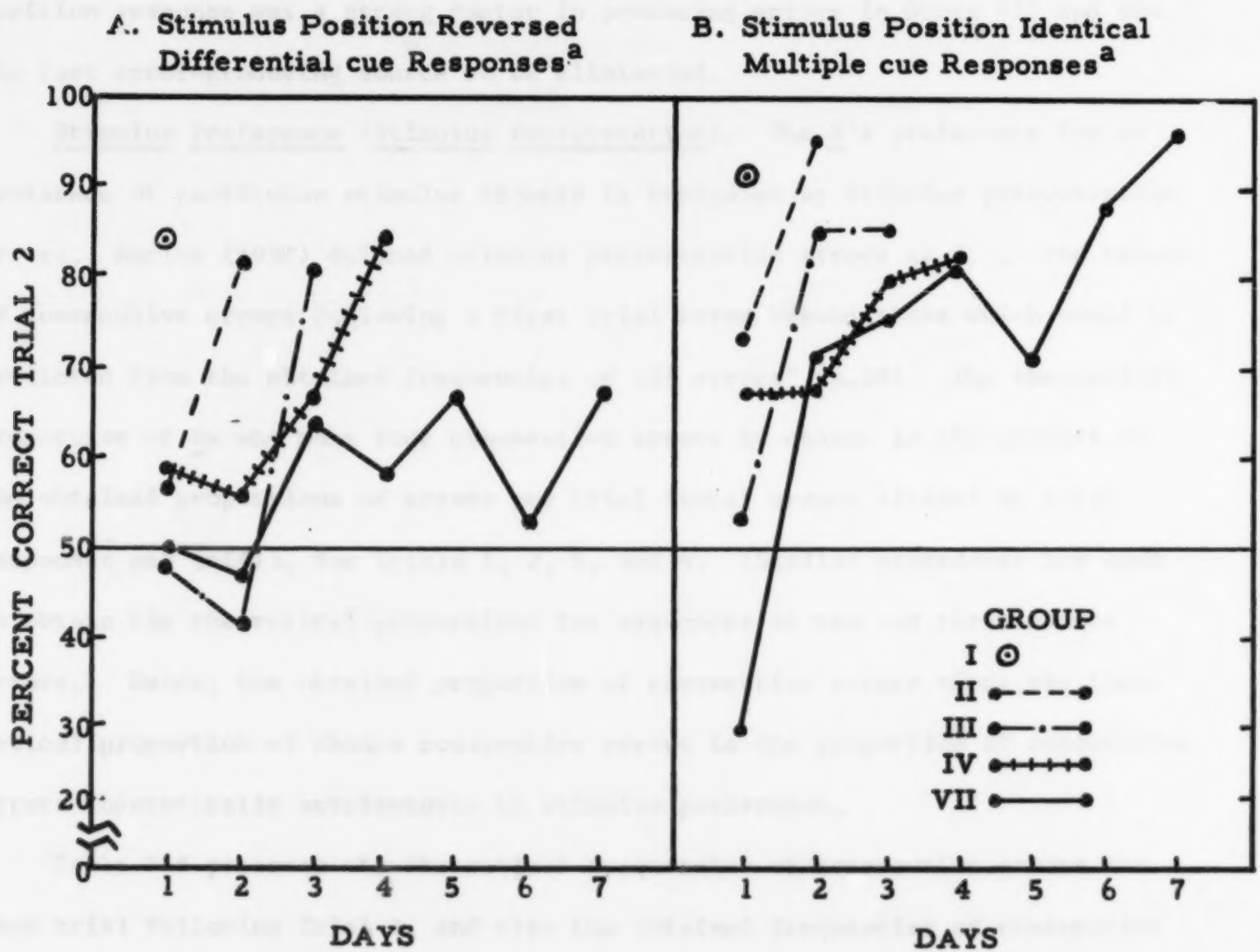


Fig. 3 - 3 Percent Correct on Trial 2 as a Function of Shift and Non-shift of Stimulus Position.

^aHarlow (1950)

depressed in all groups except Group IV. In Group VII the daily performance level on multiple cue trials (B) was markedly superior to that on the differential cue trials (A). Even on the criterion day, the errors made just before achieving criterion were made on the differential cue trials. It appears evident that a position response was a strong factor in producing errors in Group VII and was the last error-producing source to be eliminated.

Stimulus Preference (Stimulus Perseveration). The S's preference for or avoidance of particular stimulus objects is indicated by stimulus perseveration errors. Harlow (1950) defined stimulus perseveration errors as ". . .the excess of consecutive errors following a first trial error beyond those which would be predicted from the obtained frequencies of all errors" (p.28). The theoretical proportion of Ss who make four consecutive errors by chance is the product of the obtained proportions of errors per trial (total errors divided by total responses per trial), for Trials 1, 2, 3, and 4. (Similar procedures are used to obtain the theoretical proportions for sequences of two and three chance errors.) Hence, the obtained proportion of consecutive errors minus the theoretical proportion of chance consecutive errors is the proportion of consecutive errors theoretically attributable to stimulus preference.

Table 3-5 presents the theoretical frequencies of consecutive errors for each trial following Trial 1, and also the obtained frequencies of consecutive errors. It will be noted that the obtained error scores were in most cases considerably below the theoretical frequencies. The exception, Group III, contained an atypical S, who contributed a disproportionate number of stimulus perseveration scores. All of this S's errors could be attributed to stimulus perseveration; and these error scores were inserted separately into the table to demonstrate that the frequencies of Group III were inflated by this one S.

Table 3-5

Theoretical and Obtained Frequencies of Consecutive Errors

Groups	Theoretical Errors			Obtained Errors		
	Trials			Trials		
	2	3	4	2	3	4
I	13	3	3	9	3	1
II	23	6	1	17	3	1
III	37	13	3	26	16	13
				14 ^a	13 ^a	13 ^a
IV	37	11	3	25	6	1
VII	76	25	9	51	9	2

^afrequency of errors of a single atypical S.

The percentage perseveration errors equaled zero for all groups on Trials 2, 3, and 4, except Group III which totaled 0% on Trial 2, 3.5% on Trial 3, and 16.6% on Trial 4. (The effect of within-problem learning is evident in the decrease in number of errors from Trial 2 to Trial 3, and from Trial 3 to Trial 4.)

Response Shift. It has been suggested that information gained from a correct trial is less effective in eliminating errors than information from an incorrect trial (Harlow & Hicks, 1957). "Response Shift" has been defined as the tendency to make more errors on later trials after success on Trial 1 than after failure (Harlow, 1950). Table 3-6 presents the number of errors following a correct Trial 1 response, and those following an incorrect Trial 1 response.

Table 3-6

Response Shift Errors

Number of Errors following a Correct (C) and an Incorrect (I) trial 1																
	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Total	
GROUP	C	I	C	I	C	I	C	I	C	I	C	I	C	I	C	I
I	11	9													11	9
II	26	15	12	2											38	17
III	22	12	19	15	10	4									51	31
IV	16	6	12	12	13	4	7	2							48	24
VII	19	16	15	11	16	6	15	6	14	5	14	6	9	4	102	51

Group I committed approximately the same number of errors in both cases; Groups II, III, IV, and VII, however, produced about twice as many errors after a correct first trial response as after an incorrect response on Trial 1, supporting Harlow and Hicks' contention.

H-Model and Strategy Analysis

The results of the analysis of Hs (Levine model) and strategies (Bowman analysis) are given in Figs. 3-4 and 3-5.

Description of Group Behavior. Group II may have required more practice to attain criterion than Group I because of the presence of a strong WSt_p strategy, which would compete with the application of the problem solution, H_1 (see Fig. 3-5).

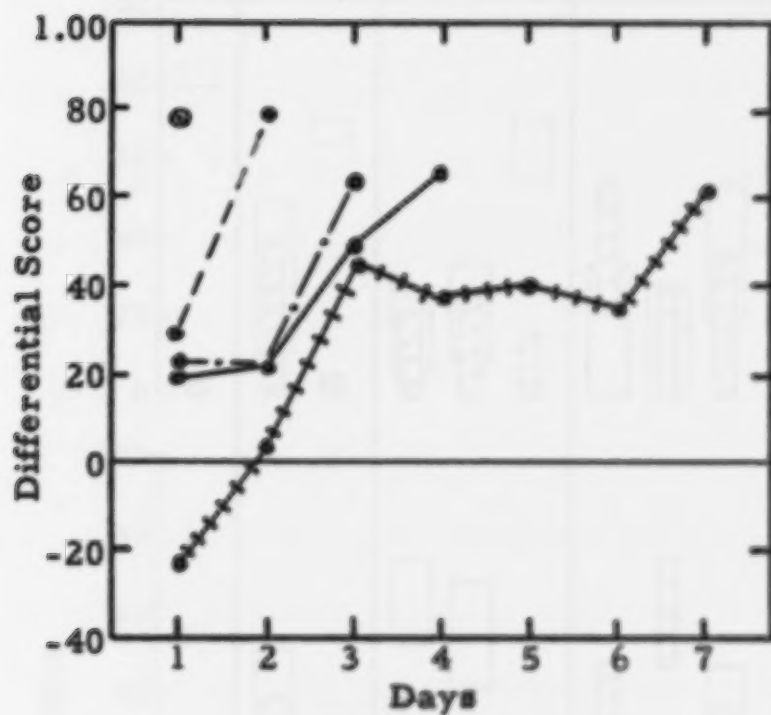
Group III displayed a more dominant WSt_p strategy than Group II. On Day 2 this strategy was combined with a strong LSh_p tendency, yielding H_3 . An initially strong LSh_0 was manifested, although WSt_0 (required for problem solution) was initially weak.

The behavior of Group IV differed from that of Group III in that WSt_p was relatively low and WSh_p high on Day 1, and this difference increased on Day 2. Furthermore, marked WSh_o was initially exhibited rather than WSt_o . In Group IV indications of H_6 appeared on Day 1 (stimulus alternation: WSh_o & LSh_o); this was partially replaced on Day 2 by a strong H_8 (position alternation). On Day 3 these tendencies were less evident, and patterns similar to those seen during the initial stages of learning in Groups II and III became evident.

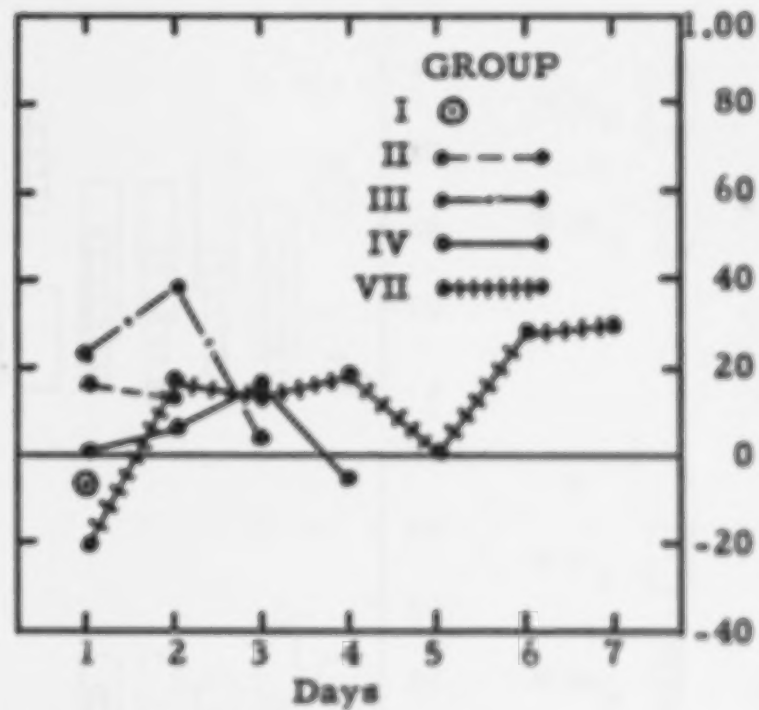
The response patterns observed on Days 3 through 7 in Group VII were similar to those seen in Groups II, III, and IV on the pre-criterion day. On Day 1 Group VII exhibited a tendency to alternate objects (H_6), combined with a vigorous position tendency (LSt_p). H_6 gained in strength on Day 2, and was combined with a strong LSh_p ; but on Day 3 the replacement of WSh_o by WSt_o substituted the H_1 hypothesis for H_6 , and the lose-position strategies became minor. WSt_p , however, became salient on Day 3 and remained in evidence through the criterion day.

Object Responses. D_a : The positive values of D_a (Fig. 3-4) indicate that H_1 was greater than H_2 . The single negative score, in Group VII, suggests that this group initially applied the complementary H_2 . The magnitudes of the D_a scores on Day 1 were ranked in order, so that these scores predicted the order in which criterion was attained. It may also be noted that Group VII reached a plateau on Day 3 which lasted for several days.

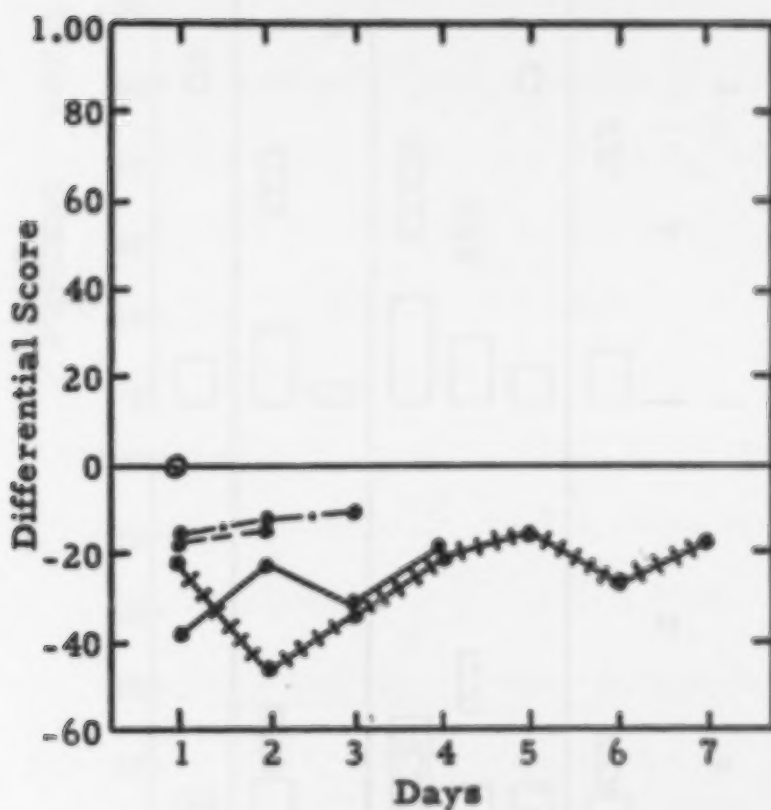
WSt_o & WSh_o : In Group I WSt_o appeared in considerable strength, while in comparison, WSh_o was of low value and had a lower limit of zero. In all other groups on criterion day, these two strategies approached, but never attained the degree of separation found in Group I. In the slower learners, Groups IV and VII, the upper limits for WSh_o were greater than for WSt_o on Day 1, and on



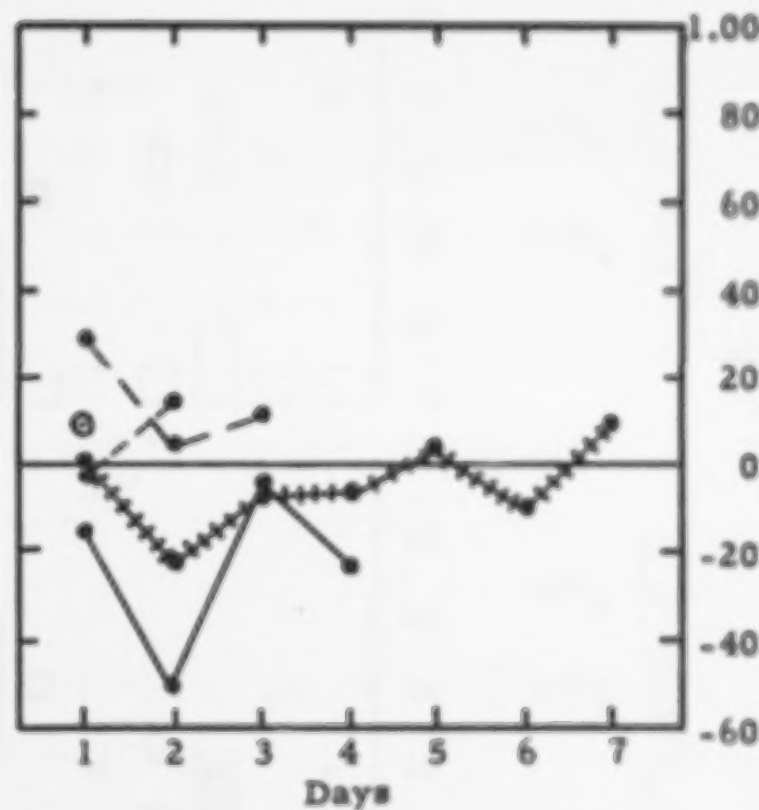
D_a : WSt_o LSh_o - WSh_o LSt_o
PROBLEM SOLUTION



D_b : WSt_p LSh_p - WSh_p LSt_p



D_x : Stimulus Preference - Stimulus Alternation



D_y : Position Preference - Position Alternation

Fig. 3 - 4 Differential Scores as a Function of Problem Blocks (days) for Preschool Groups

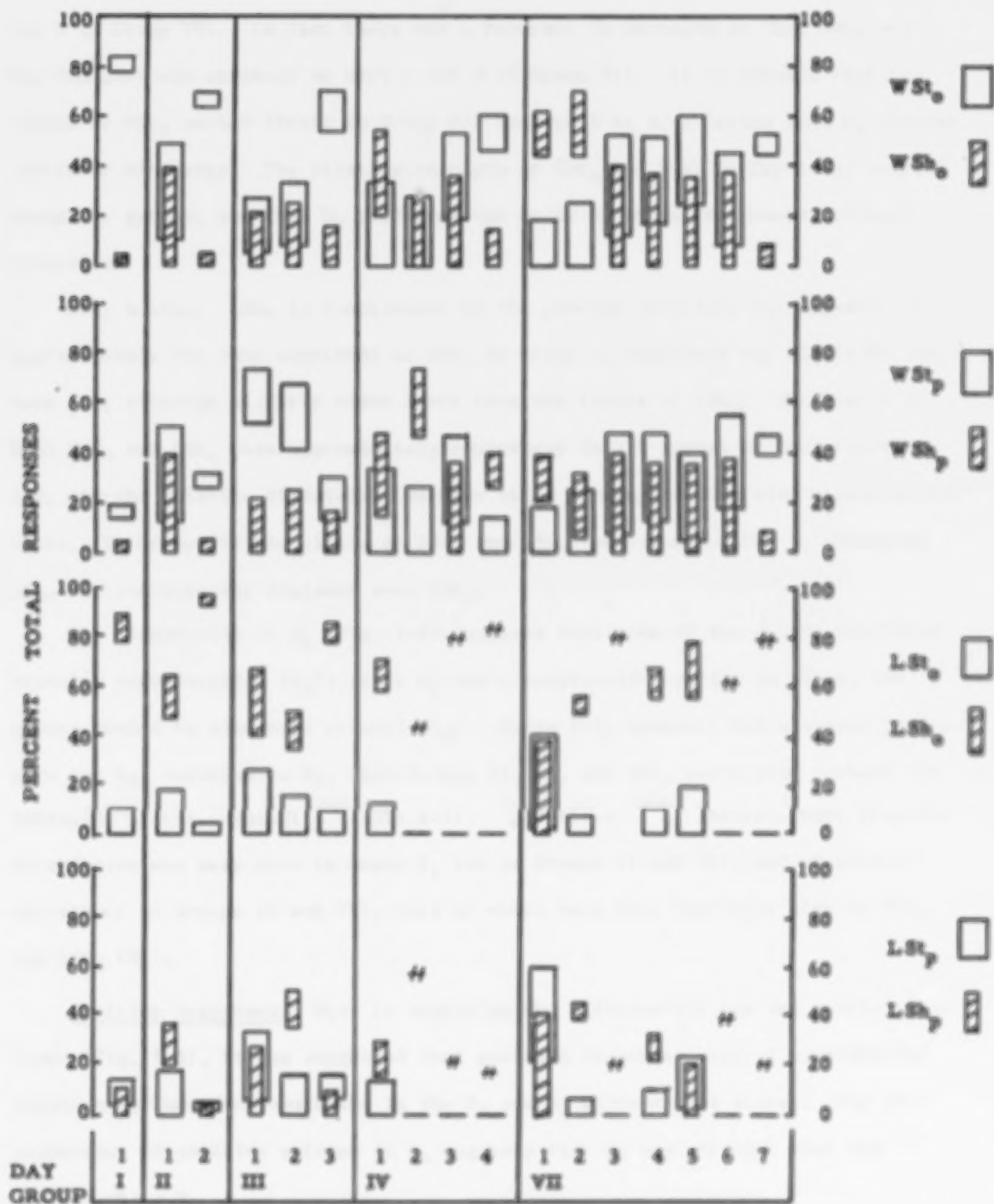


Fig. 3-5 Strategies Behavior in Preschool Children
(Bowman's Method of Limits)

Day 2 in Group VII. In fact there was a reversal in strength so that USH_0 was the dominant win strategy on Days 1 and 2 in Group VII. It is notable that the limits of USL_0 varied little in Group VII on Days 3 to 6, a period when D_A evinced little or no change. The relative strength of USL_0 and USH_0 on Day 1 was ordered among the groups, and like D_A predicted the order in which the groups achieved criterion.

LSt_0 & LSh_0 : LSh_0 (a constituent of the problem solution, H_1) appeared at approximately the same magnitude as USL_0 in Group I; similarly the limits of LSt_0 were low, although slightly wider apart than the limits of USH_0 . The limits of both LSt_0 and LSh_0 were approximately equivalent in all groups on the criterion day, and the relative differences between these strategies were also approximately equal. In Group VII the limits of LSt_0 and LSh_0 overlapped on Day 1; otherwise LSh_0 was consistently dominant over LSt_0 .

D_X : Inspection of D_X (Fig. 3-4) suggests that none of the groups exhibited stimulus perseveration (H_2); since D_X was consistently negative in value, the groups tended to alternate stimuli (H_6). Group III, however, had a lesser preference for H_6 relative to H_2 , than Groups II, IV, and VII, reflecting perhaps the inclusion of the atypical $\underline{3}$ (Table 3-5). The values of D_X indicate that stimulus alternation was near zero in Group I, low in Groups II and III, and of greater importance in Groups IV and VII, both of which were also initially high in USH_0 and LSh_0 (H_6).

Position Responses. D_Y : In comparing the differential cue and multiple cue cases (Fig. 3-5), it was suggested that position responses were of considerable importance; these are evaluated in the D_Y and D_Z differential scores. The preponderance of positive entries in D_Y suggests that H_3 was stronger than the complementary H_4 .

WSt_p & WSh_p : It will be noted (Fig. 3-5) that Group I employed WSt_p and WSh_p very little. Group II, however, displayed a stronger WSt_p and this strategy was even more prominent in Group III. WSt_p was manifested less in Group IV, as WSh_p appeared strong on Day 1 and gained dominance over WSt_p on Days 2 and 4. WSh_p appeared to present less interference in Group VII, and was weaker than WSt_p from Day 3 on.

LSt_p & LSh_p : Both LSt_p and LSh_p were at relatively low values on criterion day for all groups. Groups III, IV, and VII however exhibited an increased LSh_p on Day 2, and Group VII displayed considerable LSt_p on Day 1.

D_y : Inspection of the D_y values indicates some position perseveration, H_y , in Groups II and III, and to lesser extent in Group I. Position alternation (H_a) appeared in Groups IV and VII, with some fluctuations between H_y and H_a appearing during the last days of Group VII--including the "plateau" days.

In Group II WSt_p was greater than WSh_p , but LSt_p was less evident than LSh_p . In Group III WSt_p clearly was dominant over WSh_p , and LSh_p although low on Day 1 rose and was responsible for the shift in D_y from .29 (Day 1) to .04 (Day 2). The increased prominence of WSh_p and LSh_p (H_a) in Group IV on Day 2, relative to Day 1, was responsible for the drop in D_y from -.15 to -.52 on Day 2. As both components of H_a dropped to low levels on Day 3, D_y moved accordingly to a value of -.03. The vacillation of Group VII between H_y and H_a is reflected in the slow rise of WSt_p over WSh_p , and the rise of LSh_p over LSt_p .

Figs. 3-6 and 3-7 present the differential scores and strategies as a function of age in the preschool group. Inspection of these figures suggests that age differences were minor, with one possible exception: the younger two groups exhibited a tendency to WSt_p rather than WSh_p ; this was not true of the older two groups. This age difference is reflected in the higher values in D_x and D_y for the two younger groups.

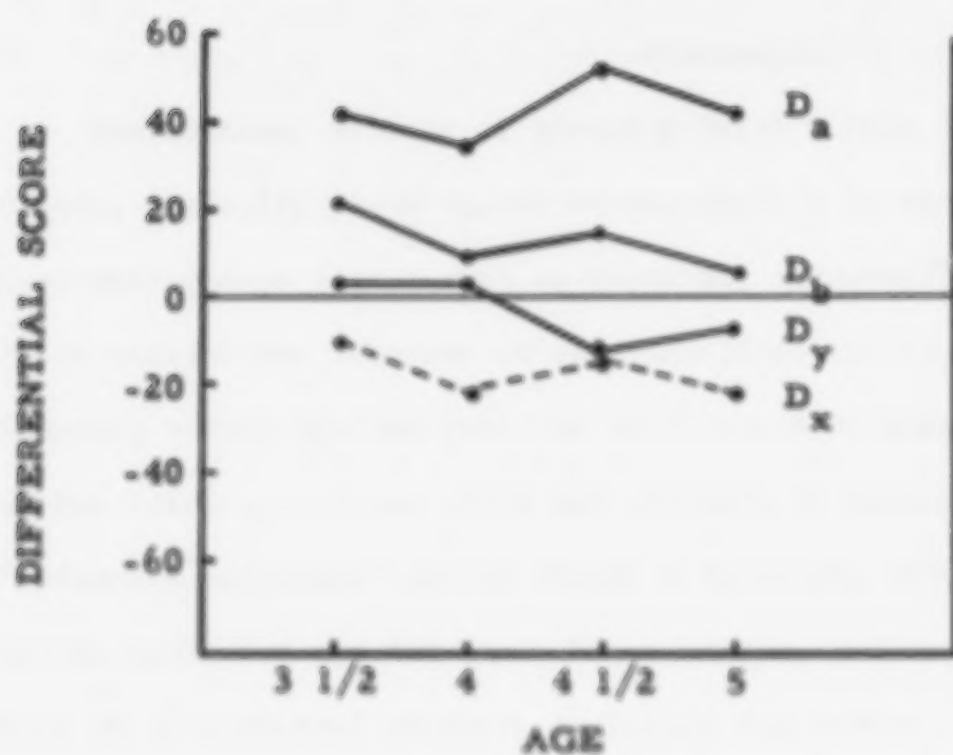


Fig. 3 - 6
Differential Scores as a
Function of Age in
Preschool Children.

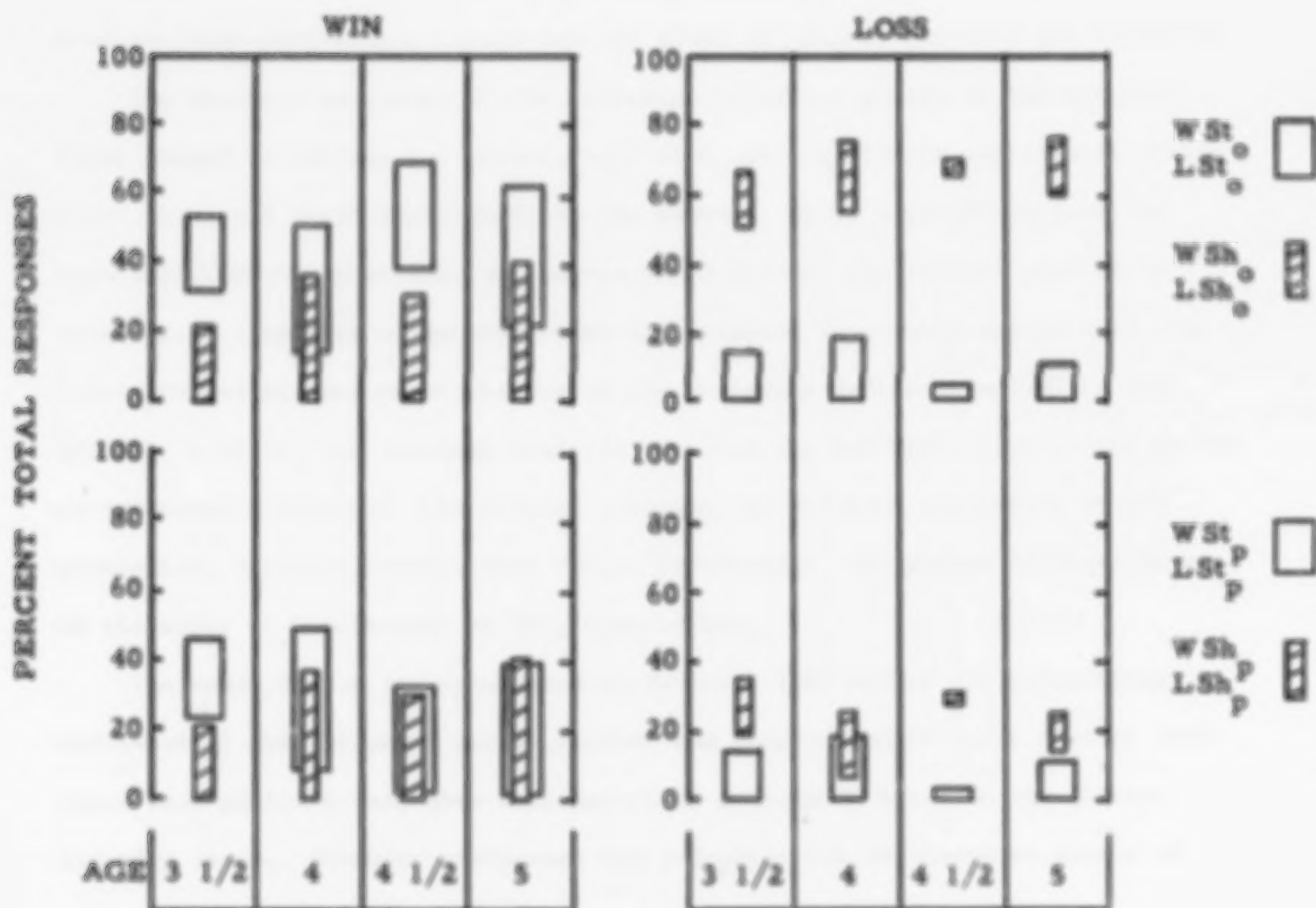


Fig. 3 - 7 Strategies in Learning Set of Preschool Children as a
Function of Age.

Discussion

Conventional methods of grouping Trial 2 data and combined Trial 2, 3, and 4 data, typically yield ogival curves similar to those of Fig. 3-1 (Harlow, 1959). Mean-performance curves such as these may oversimplify the data and may not faithfully reflect the behavior of any individual (Estes, 1960; Hayes & Fereboom, 1959). However, curves derived from the performance of homogeneous 9s can reveal details of the learning process which are obscured in mean-performance curves. The "criterion reference" method (Hayes & Fereboom, 1959) uses rate of acquisition as the basis for forming homogeneous groups, and was applied to the learning set data of 17 preschool children by Runne (in Harlow, 1949). The groups obtained were probably too small to be homogeneous, and hence her curves did not differ from the mean-performance curves usually given as typical learning set functions.

The acquisition curves of the criterion reference groups of the present study seemed to exhibit two phases, with slow but significant improvement in the first phase and rapid improvement in the second. Since a parabolic equation also described the function, the curves could reflect the initial positively accelerated component of an ogive with the terminal negatively accelerated component curtailed because of the use of the criterion reference method to form groups. However, the strategy analysis supports the interpretation of the curves as two-phase functions. The problem solution was acquired piecemeal; in all groups $L\dot{S}t_0$ appeared earlier than $US\dot{t}_0$. Furthermore, the groups differed more in the speed of development of $US\dot{t}_0$ than of $L\dot{S}t_0$.

The error factor analysis based on Harlow's 1950 method for calculating differential cue, stimulus perseveration, and response shift error factors indicated that position responses were important sources of error in the slowest learning group. Stimulus preference was evidently not an important source of

error in any group. In examining response shift, twice as many errors were found after a correct first trial as after an incorrect first trial.

The earlier acquisition of LSH_0 than WSt_0 (also reflected in the response shift data) is of theoretical importance. In Levine's model the equations for calculating the differential scores are based on the assumption that the probability of a correct response after a win is equal to that after a loss. This assumption was questioned by Bowman (1963), who therefore separated the win and loss strategies in his modification of Levine's model. Both LSH_0 and WSt_0 are 100% reinforced (since they form the problem solution), and the finding that they are learned at different rates supports Bowman's contention. These data and other findings indicate that the Bowman analysis gives more information than Levine's model.

The WSt_p strategy was the most persistent incorrect strategy, and probably accounts for the differential cue error. This strategy was 50% reinforced; but LSH_p was also 50% reinforced, yet appeared only in Groups IV and VII, and was replaced by LSH_0 earlier than WSt_p was replaced by WSt_0 .

The difference in strength between WSt_0 and WSh_0 on Day 1 predicted the order in which the groups reached criterion. There was also orderliness among the groups in the occurrence of the incorrect strategies. WSt_p strength determined the difference in practice required to achieve the criterion in Groups I, II, and III. WSh_p appeared as an additional obstacle in Groups IV and VII and had to decrease in strength before WSt_p could appear. The considerable delay in achieving criterion in Group VII may be attributed to the appearance of WSh_0 as an additional obstacle, and the persistence of WSt_p .

The groups differed in two respects: in the number of incorrect strategies employed, and in the number of problems required to inhibit the incorrect

strategies. The present data provide no evidence regarding the sources of the differences among the groups. An intensive study of the Se in each of the groups appears necessary to identify the variables which determine the group membership. These variables may be sought in personality traits such as perseveration, compulsivity, intelligence, and anxiety.¹

It is suggested that learning set acquisition hinges on the ability of the subject to structure and restructure information. It may be hypothesized that the inhibition of incorrect strategies must be especially difficult for the child who has difficulty in shifting response sets. The learning process is not just the acquisition of new responses with concomitant "passive" dropping out of the 30% rewarded (incorrect) responses, but appears to require an active process of inhibition before the correct strategies can appear and be strengthened. The difference in relative strength between WSt_1 and WSh_1 appears an important indicator of learning efficiency, and the inhibition of the incorrect strategies appears the "key" in speed of learning.¹

The application of Bowman's strategy analysis proved extremely useful in delineating the response patterns of preschool children at each stage during the learning process. It is apparent that such an analysis would prove to be valuable for the study of populations with special difficulties in learning, such as the mentally retarded, the brain damaged, and the aged. Furthermore, the method should add much basic information when applied to the data of animal Se with experimentally produced brain lesions.

¹Suggested by Dr. Eleanor Jacobs, VA Hospital, Buffalo, N. Y.

Summary

Fifty-three nursery school children were given 4-trial object-quality discrimination learning set problems until they attained a criterion. The Ss were separated into homogeneous groups on the basis of the number of problems to criterion. The acquisition curves of these homogeneous groups possessed two phases and markedly differed from learning curves resulting from mean-performance data.

An application of Harlow's 1950 method of error factor analysis indicated that stimulus perseveration was an unimportant source of error in preschool children. Response shift and position habits were important sources of error, particularly in the slower learning groups. The demonstration of the response shift error source in preschool children is of theoretical importance, as it calls into question a basic assumption of the Levine model.

The application of the two-trial Levine and Bowman equations proved to be valuable. It was found that the problem solution is acquired piecemeal; the acquisition of the Loss-shift strategy occurred earlier than the Win-stay (object) response. This difference in rate of acquisition may explain the two-phase appearance of the learning curves of the criterion-reference groups.

An orderliness in the elimination of the incorrect strategies was found. The difference in strength between Win-stay and Win-shift (object) on Day 1 predicted the order in which the groups achieved criterion. The groups differed not only in the number of incorrect strategies applied, but also in the rate of inhibition of each. It is suggested that further study might consider personality variables, as the learning process appears to require an active process of restructuring and inhibition, rather than the passive dropping out of incorrect response patterns.

Chapter 4

Discrimination Learning Set in Fifth-Grade Children¹

Little has been published on the formation of learning sets in the normal elementary school child. Several studies of mentally retarded children included small groups of normal Se as controls (e.g., Kaufman & Peterson, 1958; Stevenson & Swartz, 1958; Wischner & O'Donnell, 1961). Wischner and O'Donnell's normal Se, who had a mean CA of 6.8 years, were considerably younger than those of the other studies. Stevenson and Swartz's normal group consisted of 10 Se with a mean CA of 11.6 years, who were trained to a criterion on each problem before the next was presented; and Kaufman and Peterson included six mentally normal Se, from 9 to 12 years of age, and gave 3-trial problems. The experiment reported here used four-trial problems, presented in a single session to a group of elementary school children, all of whom were taken from the fifth grade. The purpose of the present experiment was to gather data on learning set performance for a large group of fifth-grade children, and to extract from these data the details of the learning process of the Se, through the application of Levine's (1963) two-trial W-model and Bowman's (1963) method of analyzing "strategies."

Method

Subjects. The Se were 53 children from the fifth grades of three local elementary schools. Two of the schools were situated in suburban areas with an upwardly selected socioeconomic background, and the third was in a rural setting.

¹The writers are indebted to Mrs. Doris Ebersole, Principal, Clarence Center Elementary School; Dr. Grace Gates, Principal, Harriette Hill Elementary School; Mr. John O'Neal, Principal, Sheridan Hill Elementary School; and their staffs, for their permission to use the Se of this study and their assistance in many other ways.

The Se ranged in IQ from 84 to 143 on the Lorge-Thorndike intelligence test, which was routinely administered in the schools within six months of the experimental sessions. The mean IQ was 112.6.

Apparatus. The apparatus and test materials were identical to those described in Chapter 2.

Procedure. The children were sent from their classrooms individually, and a coordinator assigned each S at random to one of several Es who worked simultaneously in individual testing rooms. After entering the testing room S was given the formal instructions of Chapter 2. At the end of the session S was asked not to discuss the procedures and was returned to his class.

Each S received training in a single session which was terminated when he reached criterion (five consecutive problems with no more than one error on Trials 2, 3, and 4). A maximum of 30 problems was presented. The administration of all of the problems in a single session was made necessary by limitations of the time during which each pupil was available in the schools.

Results

Acquisition Curves. The Se were divided into groups on the basis of the number of problems required to reach the criterion (see Table 4-1). Six groups were formed on this basis (Groups A through F), with a seventh group (Group G) consisting of Se who failed to reach criterion within the 30 problems. Three Se who met criterion on problems 25 through 28 were omitted as this group was too small for further analysis.

An examination of the characteristics of the groups indicated that no school contributed disproportionately to any one group, since the relationship between Se' school and criterion group placement was not significant ($\chi^2 = 10.91$; $df = 12$; $p > .30$); and there was no significant difference between groups in mean IQ

Table 4-1

Fifth-Grade Groups		
Group	N	No. of Problems through Criterion
A	9	5-6
B	8	7
C	9	8-10
D	6	11-14
E	6	16-18
F	6	19-22
G	6	No Criterion

($\bar{r} < 1.00$). The Pearson correlation between IQ and problems through criterion for all S_s was small and non-significant ($\bar{r} = -.07$; $t < 1.00$).

Within-problem learning was measured by subtracting each S 's mean number of correct responses on Trial 2 from his mean correct on Trial 4. The groups did not differ significantly from each other in mean within-problem learning ($\bar{F} < 1.00$), and the overall within-problem learning, indicated by a mean increase of .005 correct response from Trial 2 to Trial 4 for each S , did not differ significantly from zero ($t < 1.00$). Apparently all of the learning occurred during the first trial. (Reese's conclusion; Levinson disagrees).

Fig. 4-1 presents the mean percentages correct responses on Trials 2, 3, and 4 combined, for blocks of three problems. In general, the curves appeared to involve two phases, and to differ primarily in the duration of the first phase.

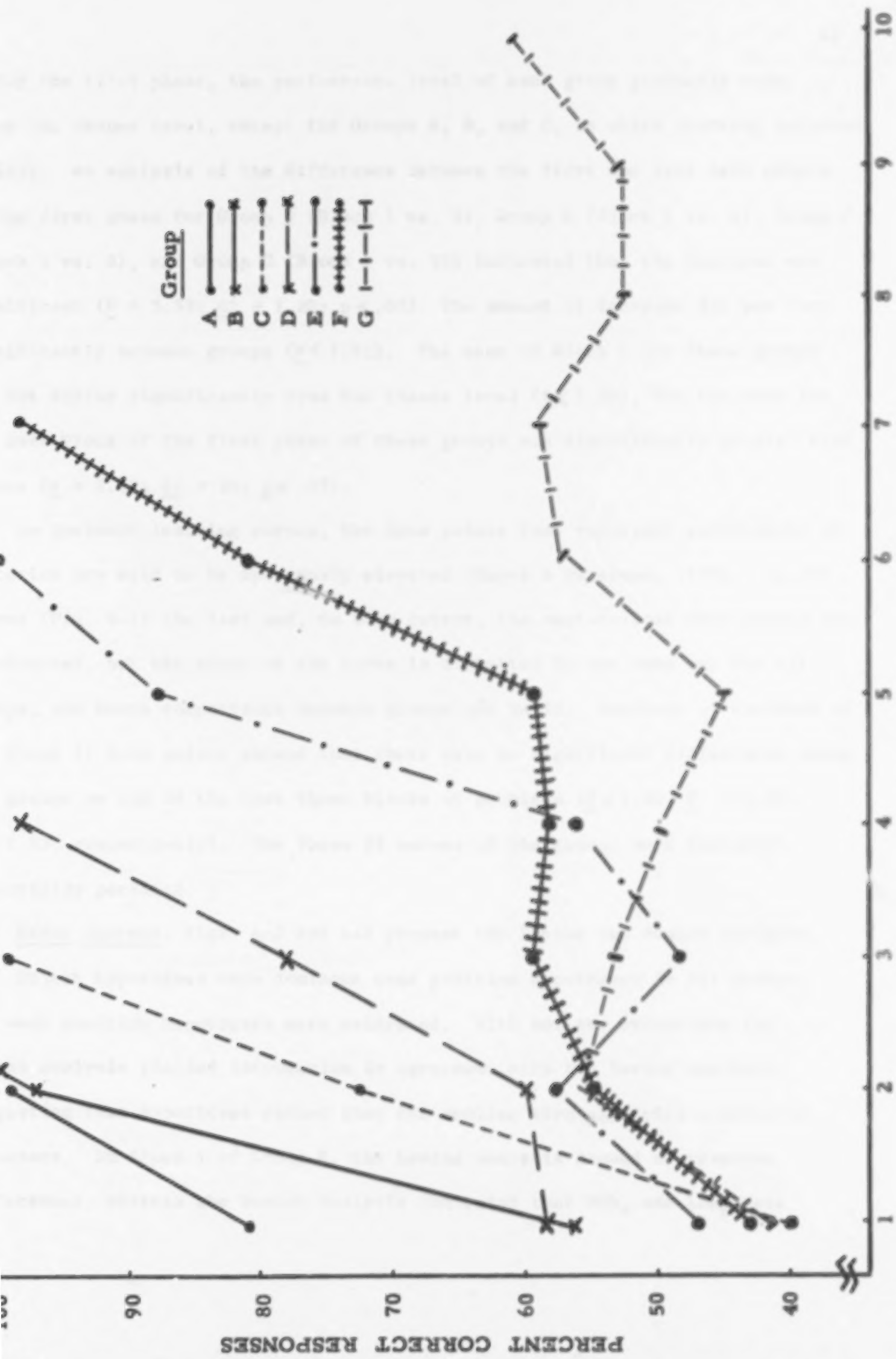


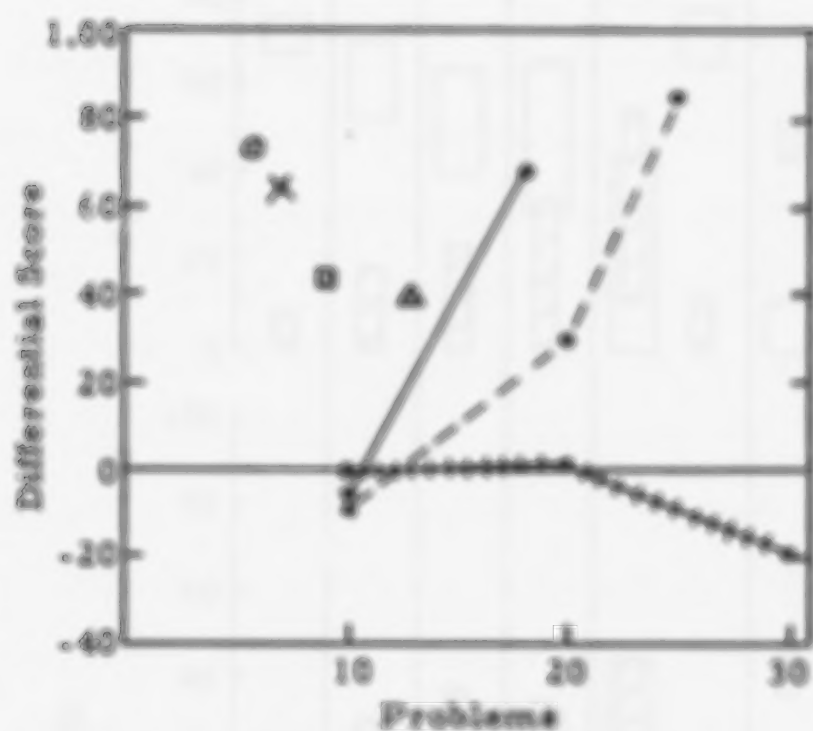
Fig. 4-1 Learning Set in Fifth-Grade Children (Combined Trials 2, 3 & 4)

During the first phase, the performance level of each group gradually rose above the chance level, except for Groups A, B, and C, in which learning occurred rapidly. An analysis of the difference between the first and last data points of the first phase for Group D (Block 1 vs. 2), Group E (Block 1 vs. 4), Group F (Block 1 vs. 5), and Group G (Block 1 vs. 10) indicated that the increase was significant ($\bar{F} = 5.59$; $df = 1,20$; $p < .05$). The amount of increase did not vary significantly between groups ($\bar{F} < 1.00$). The mean of Block 1 for these groups did not differ significantly from the chance level ($t < 1.00$), but the mean for the last block of the first phase of these groups was significantly greater than chance ($t = 2.42$; $df = 20$; $p < .05$).

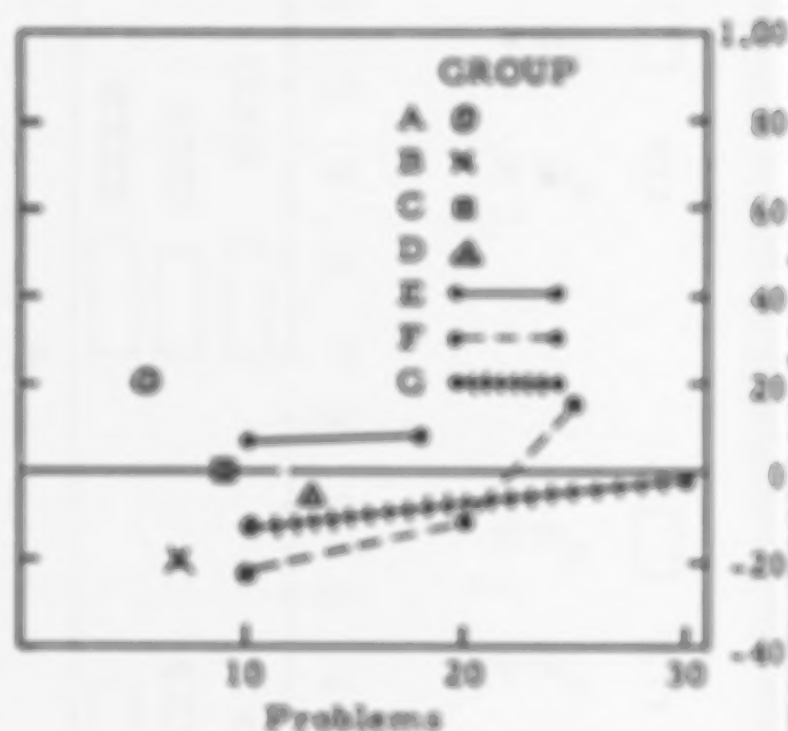
In backward learning curves, the data points that represent performance at criterion are said to be spuriously elevated (Hayes & Ferchoun, 1959). In our curves (Fig. 4-1) the last and, to some extent, the next-to-last data points are so affected, but the shape of the curve is distorted in the same way for all groups, and hence comparisons between groups are valid. Analyses of variance of the Phase II data points showed that there were no significant differences among the groups on any of the last three blocks of problems ($\bar{F} < 1.00$; $\bar{F} = 1.20$; $\bar{F} < 1.00$, respectively). The Phase II curves of the groups were therefore essentially parallel.

Error Sources. Figs. 4-2 and 4-3 present the Levine and Bowman analyses.

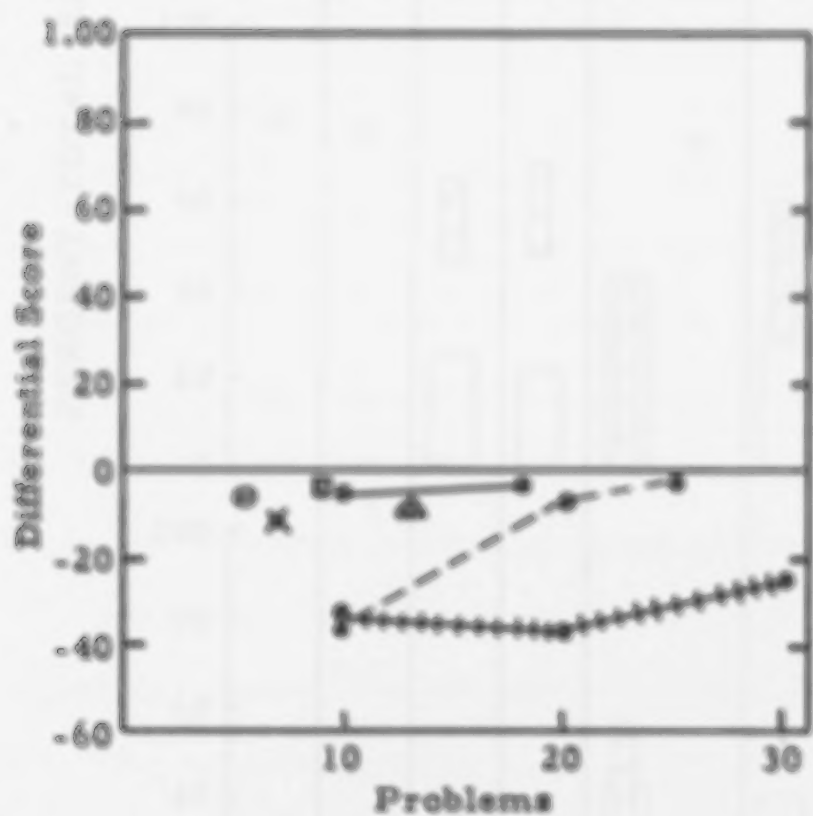
Object hypotheses were dominant over position hypotheses in all groups, but weak position hypotheses were evidenced. With but two exceptions the Bowman analysis yielded information in agreement with the Levine analysis, suggesting that hypotheses rather than the smaller strategy units controlled responses. In Block 1 of Group E, the Levine analysis showed no response preferences, whereas the Bowman analysis indicated that WSh_0 and LSh_p were



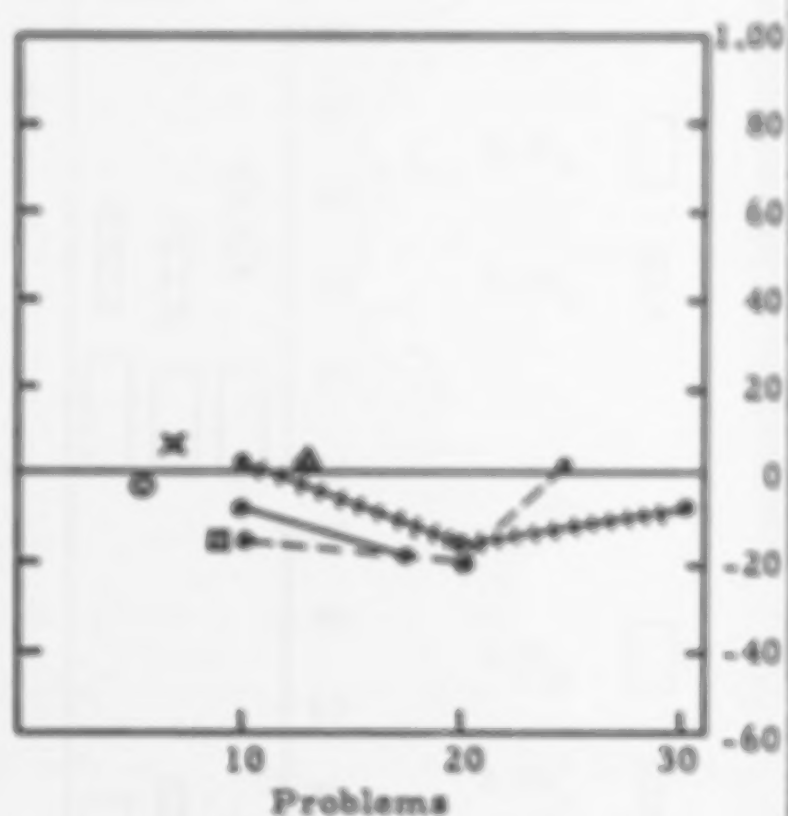
D_A : $WSt_L Sh_L - WSh_L St_L$
PROBLEM SOLUTION



D_B : $WSt_P Sh_P - WSh_P St_P$

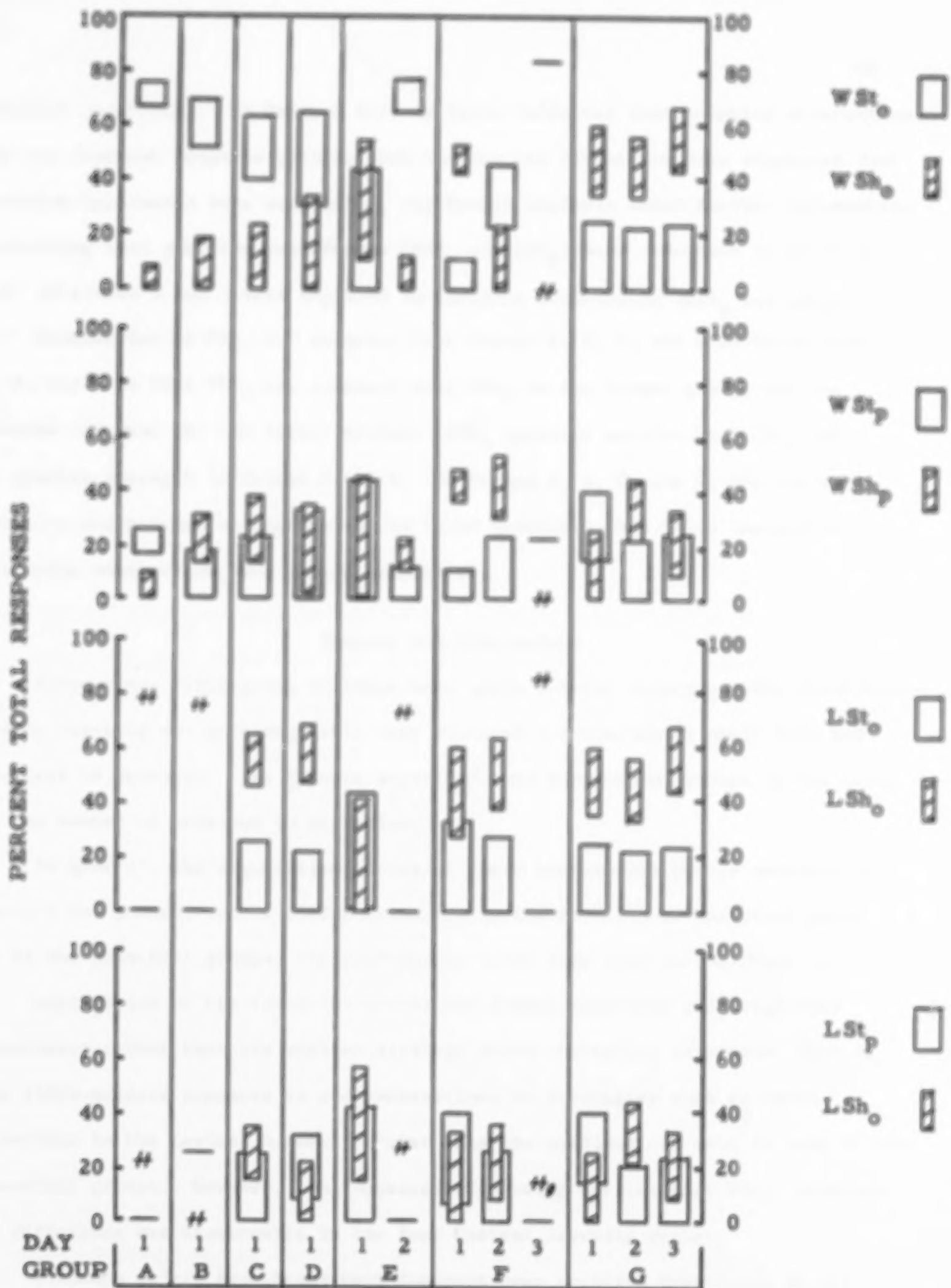


D_X : Stimulus Preference - Stimulus Alternation



D_Y : Position Preference - Position Alternation

Fig. 4-2 Differential Scores as a Function of Problem Blocks for Fifth-Grade Groups



dominant strategies. In Group G both analyses indicated that stimulus alternation was the dominant response pattern, but whereas the Levine analysis suggested that position hypotheses were negligible, the Bowman analysis added further information indicating that position preferences (WSt_p and LSh_p) were important in Block 1, and in Blocks 2 and 3 were replaced by position alternation (WSt_p and LSh_p).

Examination of Fig. 4-3 suggests that Groups A, B, C, and D differed from E, F, and G in that WSt_o was dominant over WSt_p in the former groups and the reverse was true for the latter groups. LSh_o appeared earlier than WSt_o and in greater strength in Groups F and G. In Groups A, B, C, and D, the correct solution was reached so rapidly (up to 11-14 problems) that it is impossible to determine whether LSh_o was gained before WSt_o .

Summary and Conclusions

Fifty-three fifth-grade children were given 4-trial object-quality discrimination learning set problems until they attained a criterion or until they had received 30 problems. The 53 were separated into homogeneous groups on the basis of the number of problems to criterion.

In general, the acquisition curves of these homogeneous groups appeared to involve two phases, and to differ primarily in the duration of the first phase. As in the preschool groups, the performance level rose even during Phase 1.

Application of the two-trial Levine and Bowman equations indicated that hypotheses rather than the smaller strategy units controlled responses. That is, the fifth-graders appeared to use combinations of strategies such as those described in the Levine H-model, rather than the combinations seen in some of the preschool groups. However, LSh_o appeared to develop earlier than WSt_o , although no difference was discernable in the four fastest learning groups.

Although object hypotheses were dominant over position hypotheses in all groups, weak position hypotheses occurred, and appeared to influence the rate of acquisition of the learning set.

Chapter 3

Discrimination Learning Set in College Students

Only a few studies have reported data on learning set acquisition in college-aged Se. Adams (1954) described the acquisition of a complex learning set type task by air force trainees which involved slides and linearly arranged conditional response switches, a task differing in many ways from learning set studies with stereometric stimulus objects. In a study by Levine (1963) 20 college students were given two-trial problems with cards of nonsense syllables used as stimulus objects. Levine applied his H-model to the data but made no attempt to divide this group into homogeneous criterion reference groups. The purpose of the study reported herein was to provide data on the acquisition of learning set by college students using four trial problems, stereometric objects, and a standard discrimination procedure. A homogeneous grouping of the subjects into criterion reference groups preceded the H-model and strategy analysis.

Method

Subjects. The Se were 37 college students from introductory psychology courses at the University of Buffalo (now the State University of New York at Buffalo). All Se were unpaid volunteers.

Apparatus and Procedure. The apparatus and procedure were identical to those used with fifth-grade children, as described in Chapter 4.

Results

Acquisition Curves. In order to assess the learning set acquisition curves, the Se were divided into groups on the basis of the number of problems required to attain the learning set criterion. Each group included only the Se who met

criterion on a given problem. The data of five of these groups were excluded as there were only one or two Se per group, a total of eight Se. The remaining 49 Se fell into 7 groups: 5, 6, 7, 8, 10, 11 and a group of four Se who failed to reach criterion within 30 problems. It is apparent that there was little improvement in performance in this group, as the mean scores (percentage correct responses) of this group, for successive blocks of 10 problems, were: 49%, 60%, and 57%.

Fig. 5-1 presents the curves of the six groups which reached criterion, and indicated their sizes. The curves included two phases, an early phase in which there was no improvement in performance, and a second phase which included only the criterion problems. That is, saltatory curves were obtained, with a pre-solution phase followed by a rapid rise to the criterion level. (The high level of performance on Problem 2 in Groups 7, 8, 10, and 11 probably resulted from an incorrect N, since performance was inferior on Problem 3 in Groups 8, 10, and 11. The position of the correct object in Problem 1, 2, and 3 followed the sequence 1RRR, 1LLR, 1RLR, which may have encouraged a position preference.)

Within-Problem Learning. The 57 Se were divided into five groups for the assessment of within-problem learning, which was measured by subtracting each Se's mean number of correct responses on Trial 2 from his mean correct on Trial 4. Table 5-1 presents the number of problems through criterion and the size of each group. Mean within-problem learning did not vary significantly among the groups ($F < 1.00$), but the mean of all Se (an increase of .041 correct response) was significantly greater than zero ($t = 2.78$; $df = 52$; $p < .01$).

Error Sources. The analysis of error sources was based on the five groups of Table 5-1 and a sixth group which included the four Se who did not attain criterion (Group NC).

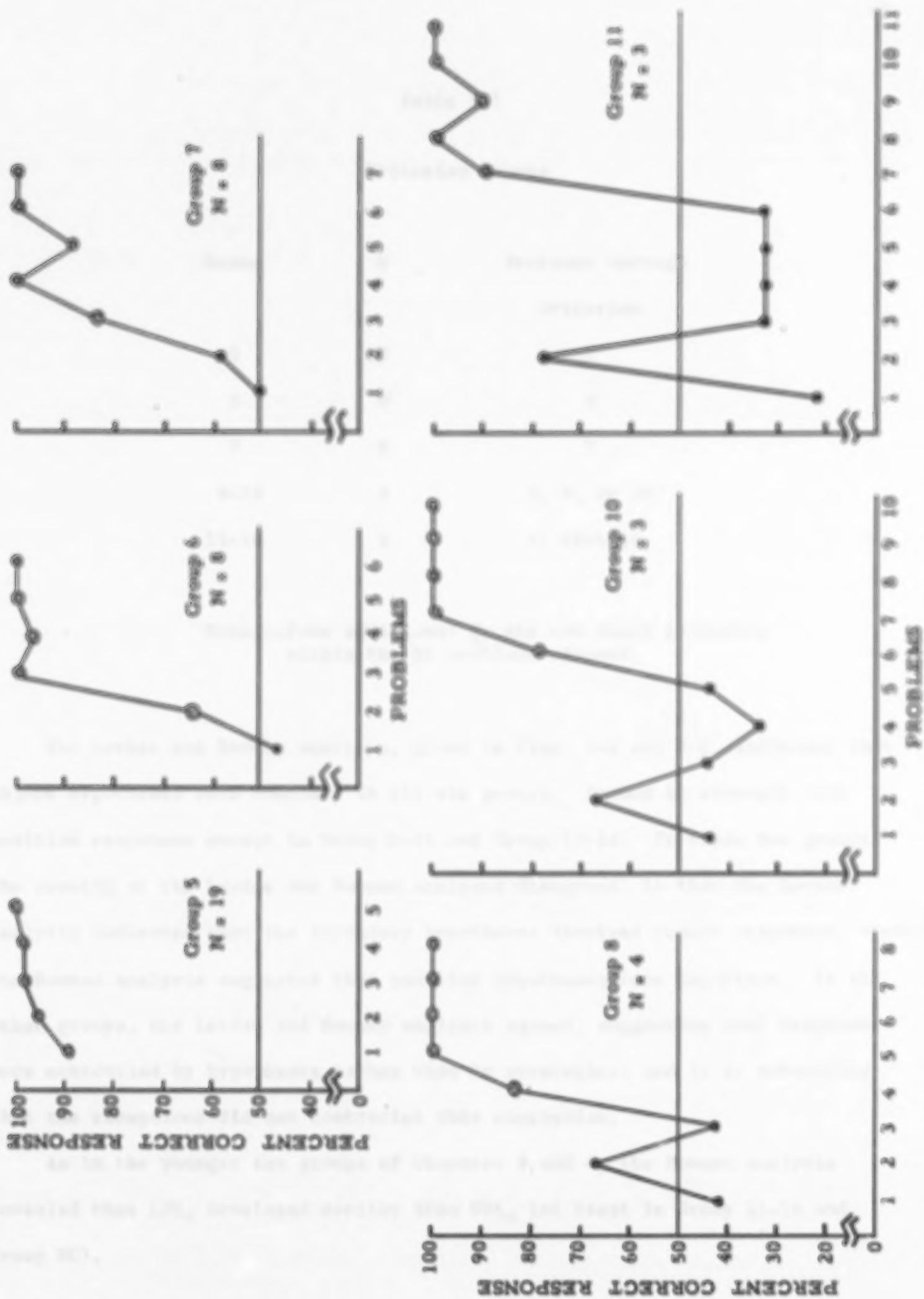


Fig. 5-1 Learning Set Curves for College Groups (Combined Trials 2, 3, & 4)
Last 5 problems (criterion)

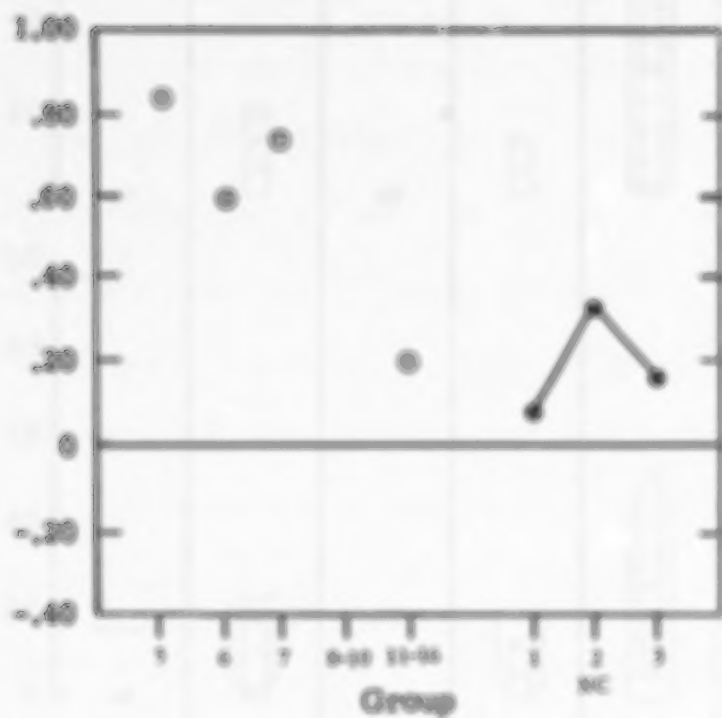
Table 3-1

Criterion Groups		
Group	N	Problems through Criterion
3	19	3
6	8	6
7	8	7
8-10	9	8, 9, or 10
11-16	9	11 thru 16

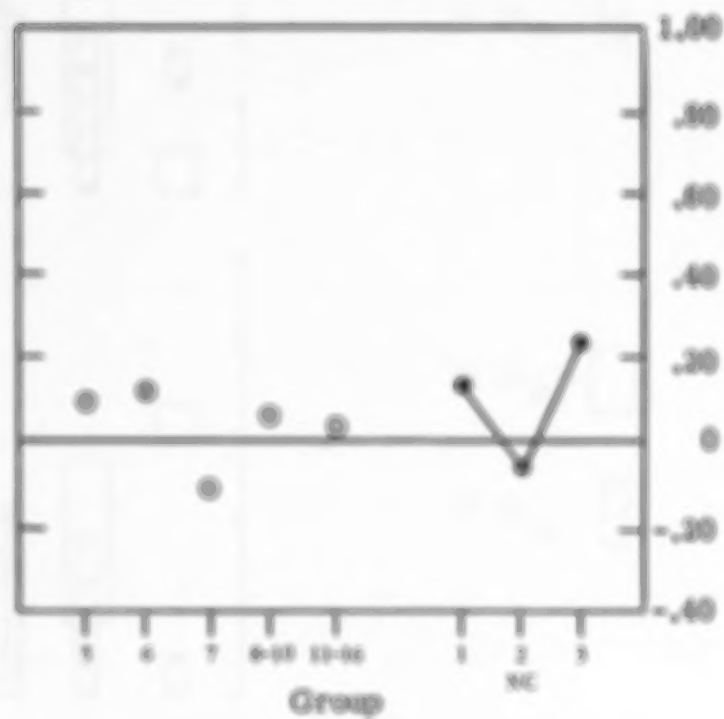
Note.--Four additional *do* did not reach criterion within the 30 problems allowed.

The Levine and Bowman analyses, given in Figs. 3-2 and 3-3, indicated that object hypotheses were dominant in all six groups. Second in strength were position responses except in Group 8-10 and Group 11-16. In these two groups, the results of the Levine and Bowman analyses disagreed, in that the Levine analysis indicated that the secondary hypotheses involved object responses, whereas the Bowman analysis suggested that position hypotheses were important. In the other groups, the Levine and Bowman analyses agreed, suggesting that responses were controlled by hypotheses rather than by strategies; and it is noteworthy that the exceptions did not contradict this conclusion.

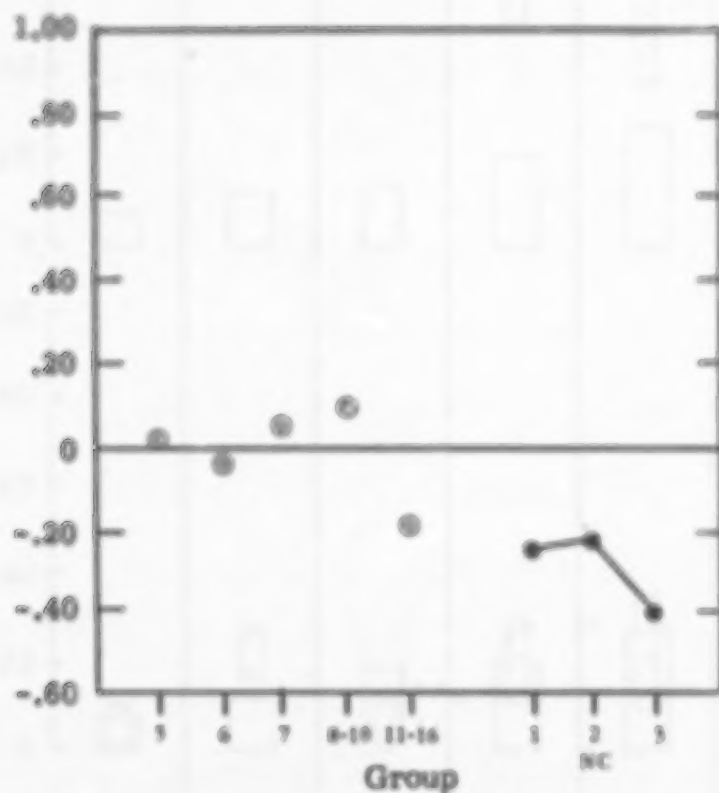
As in the younger age groups of Chapters 3 and 4, the Bowman analysis revealed that LSb_0 developed earlier than USt_0 (at least in Group 11-16 and Group NC).



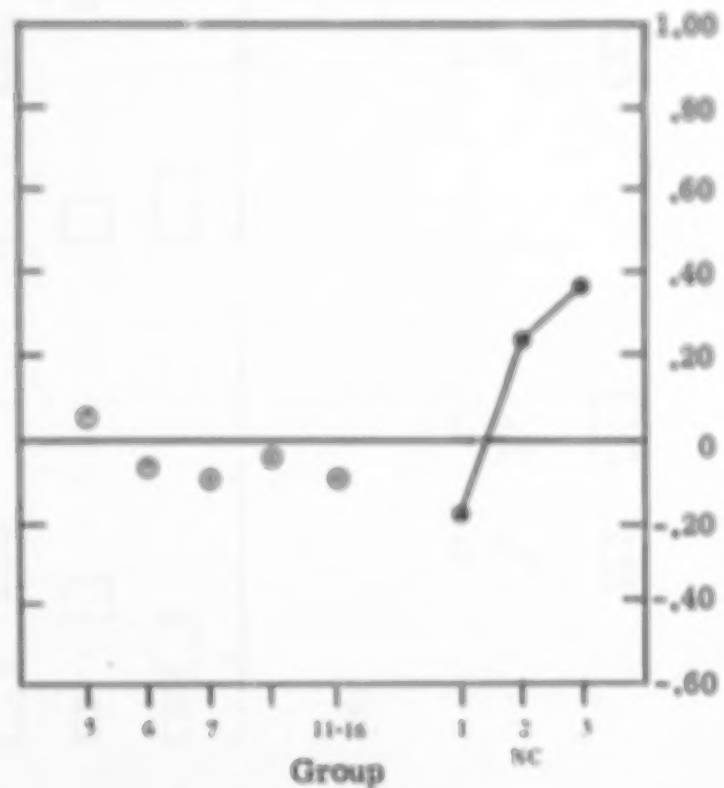
$D_A: WSH_{Lsh} - WSH_{Lsh}$



$D_B: WSH_P Lsh_P - WSH_P Lsh_P$



$D_X: \text{Stimulus Preference} - \text{Stimulus Alternation}$



$D_Y: \text{Position Preference} - \text{Position Alternation}$

Fig. 5 - 2 Differential Scores for College Groups

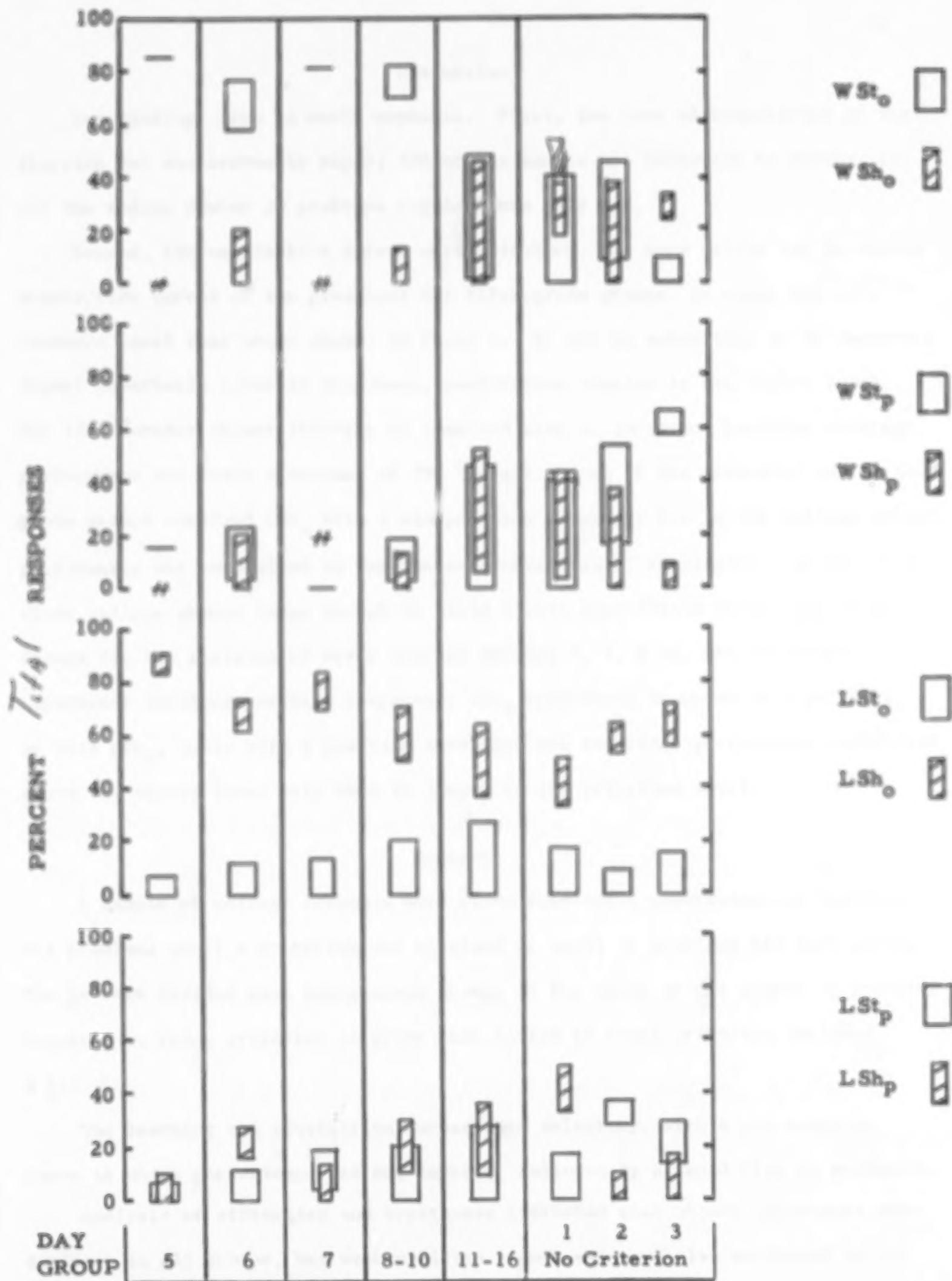


Fig. 5 - 3 Strategies in Discrimination Learning Set of College Group

Discussion

Two findings seem to merit emphasis. First, the rate of acquisition of the learning set was extremely rapid; 93% of the sample met criterion by Problem 16, and the median number of problems required was only 6.7.

Second, the acquisition curves were saltatory, but were unlike the two-phase acquisition curves of the preschool and fifth-grade groups, in which the performance level rose above chance in Phase 1. It may be noted that if an incorrect object hypothesis controls responses, performance remains at the chance level; but if a correct object strategy is combined with an incorrect position strategy, performance can reach a maximum of 75% correct. Some of the preschool and fifth-grade groups combined LSh₀ with a win-position strategy; but in the college groups, performance was controlled by hypotheses rather than by strategies. In the only three college groups large enough to yield stable acquisition curves and large enough for the analyses of error sources (Groups 5, 6, & 7), the incorrect hypotheses involved position responses; LSh₀ apparently occurred only with WSt₀ or with WSh₀, never with a position strategy, and therefore performance could rise above the chance level only when it jumped to the criterion level.

Summary

A sample of college freshmen were given four-trial discrimination learning set problems until a criterion was attained or until 30 problems had been given. The SS were divided into homogeneous groups on the basis of the number of problems required to reach criterion (A group that failed to reach criterion included 4 SS).

The learning set acquisition curves were saltatory, with a pre-solution phase in which performance did not improve, followed by a rapid rise to criterion.

Analysis of strategies and hypotheses indicated that object hypotheses were dominant in all groups, but weak position hypotheses were also evidenced in the slower learning groups.

Chapter 6

Discrimination Learning Set in the Aged

It is generally agreed that old Ss learn more slowly than the young; but some objections have been proposed to this view, on the basis that a narrow and unrepresentative range of learning tasks has been used (Lorge, 1956). As aged Ss are disproportionately handicapped by timed or paced conditions (Canestrari, 1963), the deficit in learning performance may not necessarily result from a deficit in learning ability. The application of the discrimination learning set task should prove useful in extending the range of learning tasks applied to aged Ss, and should be of particular interest in that the learning set task is neither timed nor paced. No previous studies have dealt with the learning set performance of aged Ss.

The series of investigations reported here sought to provide information on the ability of the aged human to acquire discrimination learning set, using four-trial problems. The Ss tested included only apparently healthy, normal men and women at least 60 years old. About half of the sample studied was drawn from denominational homes for the aged, and half from a community day center for senior citizens.¹ A small additional sample of volunteers was taken from the community of retired college faculty.

Seven experiments were conducted and are reported here in Part I in the order of their occurrence. Unexpected problems arose in attempting to bring an entire group of Ss to criterion, and involved a number of procedural adjustments with various groups of aged Ss. A great deal of unusable data was accumulated before a substantial group that reached criterion was collected. We omitted Ss whose data

¹We are indebted to the cooperating institutions and Golden Age groups, and their directors and staffs, for their kind and helpful assistance. All are located in Buffalo, New York.

were incomplete because they missed sessions, became ill, or died. Part II of this chapter reports the analyses from combined data of all the Ss that yielded usable data.

Part I

Experiment 1

Method

Subjects. The Ss were 20 residents in a home for the aged, and ranged in age from 68 to 85 years. None was a native-born American, and most were illiterate. The Ss were unpaid volunteers, and had been identified by the director of the institution as being of normal intelligence and free of psychiatric disorder. The institution provided an active and varied recreational program for the residents, and the residents were unoccupied only by choice. Individuals roomed together, two or three to a room, and group morale appeared excellent. Physical and occupational therapy were provided on a full-time basis, and medical and nursing staff were in attendance. Medical specialists, such as podiatrists, made frequent visits. Beauticians were available, and residents could earn money in a work program.

Apparatus. The apparatus and test materials were identical to those described in Chapter 2, except that tokens (buttons) were used as rewards. The administrative staff of the institution requested the substitution of tokens for the candy rewards which had been used with the younger groups.

Procedure. As a result of preliminary discussions, the members of a social club within the institution adopted the proposed study as a group project, and pledged their cooperation before the experimental training began. The director of the institution introduced one of the most popular residents of the home, who, as sponsor, spent several days introducing the Es to each of the Ss. The initial interview included a description of the proposed project and a request that S participate.

Each S was contacted several times before the experiment began; the introductory visit was followed by encounters in the lunchroom and halls, and a visit to set the appointment date. Initial rapport appeared to be favorable.

On the basis of the data for children (see Chapter 3), it was estimated that three testing sessions would be required, and the plan was therefore to administer 30 problems, at the rate of 10 per day. To initiate each session S was met in his room or in the work program quarters, and conducted to one of several testing rooms. The standard instructions were administered and the use of the tokens was explained. A container for the tokens was placed on S's side of the apparatus, and it was understood that S would return the tokens at the end of the test period. The session was terminated after S was cautioned not to discuss the experiment with other residents, and had been escorted to his living quarters.

Results and Discussion

The results were disappointing, in that of the 20 Ss tested, only one, a woman of 68, met criterion. Three Ss refused to continue after the first session, and two others after the second. The data of the other Ss showed no evidence of learning.

In post-testing interviews, it was discovered that the favorable group atmosphere had been attenuated by one S who reached criterion on the first day and taunted the others with her success and their "stupidity."

Several Ss stated that the sessions would have been more interesting if pennies had been used as rewards. The buttons offended some, who felt that they were "too old to play with buttons.". Other Ss referred to games of chance seen at fairs, and indicated that they believed that sleight of hand was employed, or that it was only chance that determined the reward.

On the basis of this experience, the following procedural modifications were adopted for the subsequent studies of the aged. (a) A popular person from each group of potential Ss served as a sponsor to introduce the Es to each potential S

individually in a preliminary interview. (b) Pennies were used as rewards. (c) The Ss who achieved criterion received "misinformation" trials immediately after the criterion was reached, and no overt indications of success were given by E. (d) A larger number of test sessions was given.

Experiment 2

Method

Subjects. The Ss were 16 residents in a home for the aged, and ranged in age from 74 to 97 years. None was a native-born American, and the average educational experience was equivalent to about two years of elementary school. The director of the institution selected these Ss as being free of known psychiatric disturbance and free of known central nervous system organicity. The institution was housed in modern buildings, with large individually decorated living quarters, each room occupied by one person. Although some recreational programs were available several mornings and afternoons each week, much of the time was unoccupied by planned activities. Residents spent a great deal of time in their rooms, knitting, reading, or watching television.

Apparatus. The apparatus and test materials were identical to those described in Chapter 2, except that pennies were substituted as rewards. This modification was continued during all the subsequent work with the aged.

Procedure. The director addressed the entire group during a lunch hour and briefly described the research as pleasant and important, introduced the Es, and strongly requested that those contacted should volunteer. He selected a sponsor-resident, well acquainted with all the Ss, who was willing to introduce the Es to each S individually. During the initial visit, each S agreed to one session, and providing that this was found pleasant, the S would then be committed to a minimum of 10 sessions. Suggestions were made that each S refrain from discussing his

experiences, as this would spoil the experiment.

Since each S resided in a private room, the test materials were placed on mobile stands and wheeled from room to room. During the initial session, monetary rewards were introduced, and S was again cautioned to refrain from discussing the experience with others in the home.

Results and Discussion

Six of the Ss reached criterion in one to five days, and an additional S achieved criterion on the tenth day. The 9 Ss who had not reached criterion by the tenth session participated in 3 extra sessions; one of these Ss attained criterion on Day 13. The experiment was terminated as the Ss had become anxious and began to persist in questioning why sessions were continued with some and discontinued with others.

Since only half of the Ss reached criterion in 13 or fewer sessions, it was clear that additional sessions were necessary to bring an entire group to criterion, and 20 sessions were proposed for the next attempt. To prevent the development of negative intra-group feelings, all Ss would be carried through all sessions, and those who attained criterion would be given "misinformation" trials and then random trials to the end.

Experiment 3

Method

The Ss were 25 residents, 79 to 93 years of age, in an institution which merely housed the Ss. The house was old and unattractive; no attempt was made to provide other than housing and meals for the residents, most of whom were on welfare. The institution was selected on the recommendation of an advisor from the Council of Churches, as the director was interested in bringing visitors from the community into the home.

The director introduced the Es and their purposes very briefly and perfunctorily requested the residents' cooperation. The residents appeared, on further acquaintance, self-absorbed, with little interest in the outside world or in the abstract benefits that could accrue from our investigation. The introductory procedures were carried out as described in Experiments 1 and 2, and took place in the early part of December.

Results and Discussion

After several weeks of sessions the test schedule was disrupted as residents received Christmas guests or left for visits with their families. Several parties increased the level of excitement in the home, and a number of Ss found it difficult to reserve the time for their test sessions and requested that they be discontinued. We completed from 15 to 18 sessions with all Ss, but rather than continue Ss against their will, it was decided to terminate the experiment. As there was little evidence of performance change in any S, we began to question the motivational level.

The Christmas season was an unfortunate time to gather data and our motivational controls were poor. Hence, we decided against the use of data from this group, but on the basis of this experience, we projected at least 30 sessions for the next group of Ss.

Experiment 4

Method

Subjects. The Ss were 20 residents in a home for the aged, which cared for both indigent welfare cases and financially able individuals. They ranged in age from 72 to 92 years, and were mainly American-born, with an educational attainment equivalent to less than an elementary school education. The Ss were selected by the director of the institution as being free of known psychiatric and neurological disturbances. The building in which the institution was housed was old, crowded, and

somewhat depressing in appearance. There was no formal activity program, but a television set was provided on each floor.

Procedure. The director spoke to the group, and a sponsor-resident introduced the Es to each potential S. Each S was visited individually and agreed to cooperate for 30 sessions, with more sessions possible if necessary. After 30 sessions were completed the Es decided to continue the testing program as long as it was possible, and it was not terminated until 45 sessions were completed. Testing was conducted in one of several testing rooms.

Results and Discussion

Of the 20 Ss, 1 died, 7 did not reach criterion in 45 sessions, and 12 reached criterion in 1 to 37 sessions, with a median of 25 sessions. The experiment was terminated at Session 45 because no further progress was evident, and the Ss were losing interest.

It was proposed that a sample be obtained from a home with a full-time work and recreational program as institutionalized Ss may not be representative of the aged population as a result of dwelling in a relatively non-stimulating environment. The misinformation trials were effective, and the group morale was satisfactory almost to the end, when the Ss tired of the sessions and no longer felt committed as the pledged 30 sessions had long been passed.

Experiment 5

Method

The Ss were 30 residents in the home sampled in Experiment 1. The age range and other subject characteristics were similar to those described in Experiment 1. A return was made to this home to secure a group in an institution with a full-time work and recreational program. The group atmosphere was conducive to a second attempt at this home with a new sample of Ss, since all previously tested Ss had had

no more than three sessions and had displayed no learning (the one S who had reached criterion no longer resided in the home).

Results and Discussion

The experiment was discontinued at the twelfth session when the experimenters became suspicious of contamination. Some Ss reached criterion in one errorless session after a series of sessions at the chance level; other Ss performed erratically, fluctuating between high and low scores on successive days. The group ties in this institution were unusually cohesive so that the Es began to suspect that the subject pool was contaminated. The experiment was therefore terminated, and the entire data collected were omitted.

Experiment 6

Method

The Ss were 87 participants at a Day Center operated for senior citizens by the City of Buffalo. Most were native-born American with an educational attainment equivalent to less than an elementary school education. They ranged in age from 60 to 84 years. The center provided a program which included dancing, Bingo, discussion groups, outings, etc. Some Ss came in 5 days a week, but many missed sessions because they were ill or busy elsewhere. Most Ss averaged about two sessions a week.

Results and Discussion

Twenty-six Ss, ranging in age from 61 to 83 years, reached criterion in 1 to 18 sessions, with a median of 6.5 sessions. The other 61 Ss received 1 to 25 sessions, and did not reach criterion. Of these latter Ss, 39 received from 1 to 3 sessions, 11 received 4 to 9 sessions, 8 received 10 to 19 sessions, and 3 received 20 or more sessions. The group atmosphere was strongly in favor of the testing program; and the test session was considered one of the center's activities, to the extent that it was "mandatory" for new arrivals to join in being tested. Therefore, many indi-

viduals were tested who came but once or twice to the center, and on one day a group of 20 people was tested, which was later discovered to be members of a club from another city visiting for a day.

The sample used in this experiment differed from the other groups tested, in that the average age was lower; even though some Ss were in their 70's and 80's, most were in their 60's. Furthermore, this group resided in the community, either with their children or in their own homes, and hence retained a degree of independence and stimulation which probably differed from most of the institutionalized samples.

Experiment 7

Experiment 6 yielded a good-sized sample of Ss brought to criterion, but the sample lacked the equivalent of an elementary school education. For Experiment 7 a group of retired college faculty members was tested.

Method

The subject pool consisted of retired faculty members from two local colleges; all but one had the Ph.D. degree. Each person was reached by telephone and told that we were studying the performance of various segments of the community, and had a special need for a sample of subjects with considerable intellectual attainment. We requested permission for one session to be held at their convenience in their own home, with the understanding that if the task was found unobjectionable, there would be a maximum of 10 sessions. Eleven Ss consented to be tested. They ranged in age from 65 to 72 years.

Results and Discussion

Of the 11 Ss, 9 achieved criterion in 3 days or fewer; and 2 refused to continue after the fourth session, in which they had achieved but chance performance. We found the Ss to be defensive and easily frustrated at the lack of immediate solution and explanation, but it is readily apparent that this group was consi-

derably superior to the other aged groups tested.

Part II

Two types of analysis are presented in this section. First, the different samples are compared since the data in Part I suggest that there were differences between samples; and second, criterion reference groups are compared to provide data about the process of learning set acquisition.

The Ss from the samples were combined and redistributed into two sets of criterion reference groups on the basis of the number of days to criterion (Table 6-1). The first set, Groups 1, 2, 3, 5, 6, and 7, was composed of Ss who were homogeneous with respect to days to criterion and who met criterion in 1, 2, 3, 5, 6, or 7 days, respectively. The second set, Groups A through E (Table 6-1), was composed to utilize the data of the many Ss who attained criterion between 8 and 37 days, and each group contained Ss who met criterion within 3 or 4 days of each other. Group A, Ss who met criterion in 4 to 6 days, includes some Ss also represented in Groups 5 and 6, and was deliberately constructed to overlap with the first set of criterion reference groups. The data of 2 Ss, who met criterion on Day 18 and Day 21, were omitted as they could not be fitted into any of the groups.

Table 6-1

Criterion-Reference Groups

Group	n	Days Through Criterion	Group	n	Days Through Criterion
1	12	1	A ^a	9	4- 6
2	6	2	B	5	8-11
3	4	3	C	6	13-17
5	4	5	D	5	24-27
6	3	6	E	3	35-37
7	4	7	NC ^b	21	No Criterion

^aIncludes Ss in Groups 5 and 6, and two others who met criterion on Day 4.

^bIncludes all no-criterion Ss who received at least 12 days of testing.

The no-criterion Ss were a special problem for analysis in that some Ss failed to achieve criterion in 15 days of training, others received 20 and up to 45 days of training. In addition, a large number of Ss from the day-center sample received 11 or fewer days of training, as they had appeared at the center for 11 or fewer days of activities. Since the number of Ss who received at least 12 days of training provided an adequate sample of no-criterion Ss, the data of Ss with fewer days of training were omitted from the response pattern analysis. It should be noted that the number of Ss in the no-criterion group was not the same at all data points, since an S tested for 15 days appears only in the first 3 blocks, whereas one tested for 45 days appears in all 9 blocks. Table 6-2 gives the number of no-criterion Ss represented in each 5 day (50 problem) block.

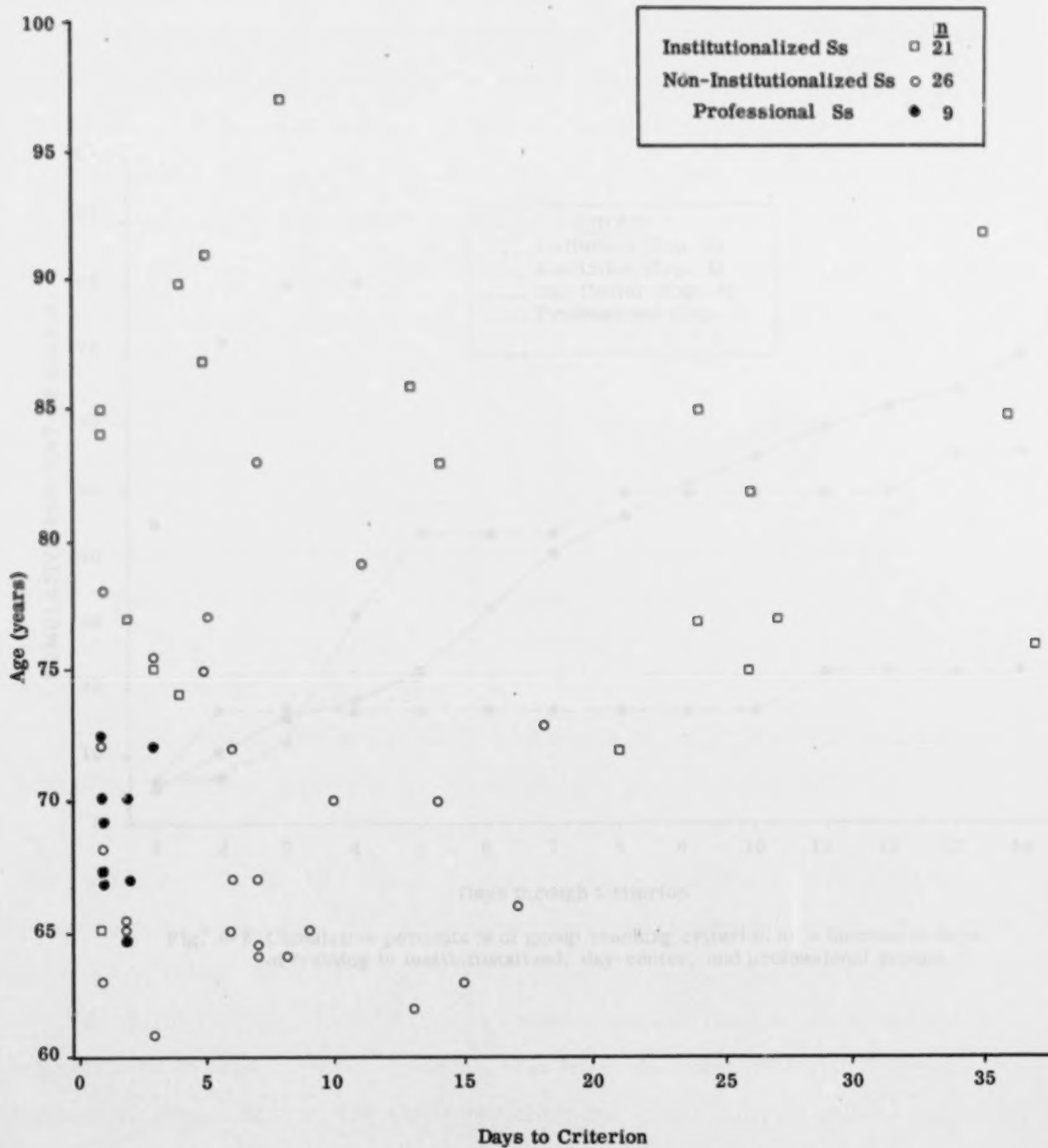
Table 6-2
Number of No-Criterion Ss Represented at Each Data Point

Blocks of 50 Problems	1	2	3	4	5	6	7	8	9
Number of <u>Ss</u>	21	21	20	11	7	6	5	5	5

Speed of Acquisition

Fig. 6-1 presents a scattergram of all the Ss who reached criterion, relating age of S to the number of days S required to attain the criterion. The Pearson correlation between these two variables was .31 ($p < .025$), but when the 12 Ss of Experiment 4 were omitted, the correlation for the remaining 44 Ss dropped to .00, indicating that the correlation of .31 was probably spurious.

Fig. 6-2 compares the 4 groups which yielded usable data (Experiments 2, 4, 6, & 7), on the basis of the cumulative percentage of each group reaching criterion as a function of days of training. This graph was terminated on Day 14, which was the last day of testing for the Ss of Experiment 2: the differences between the groups



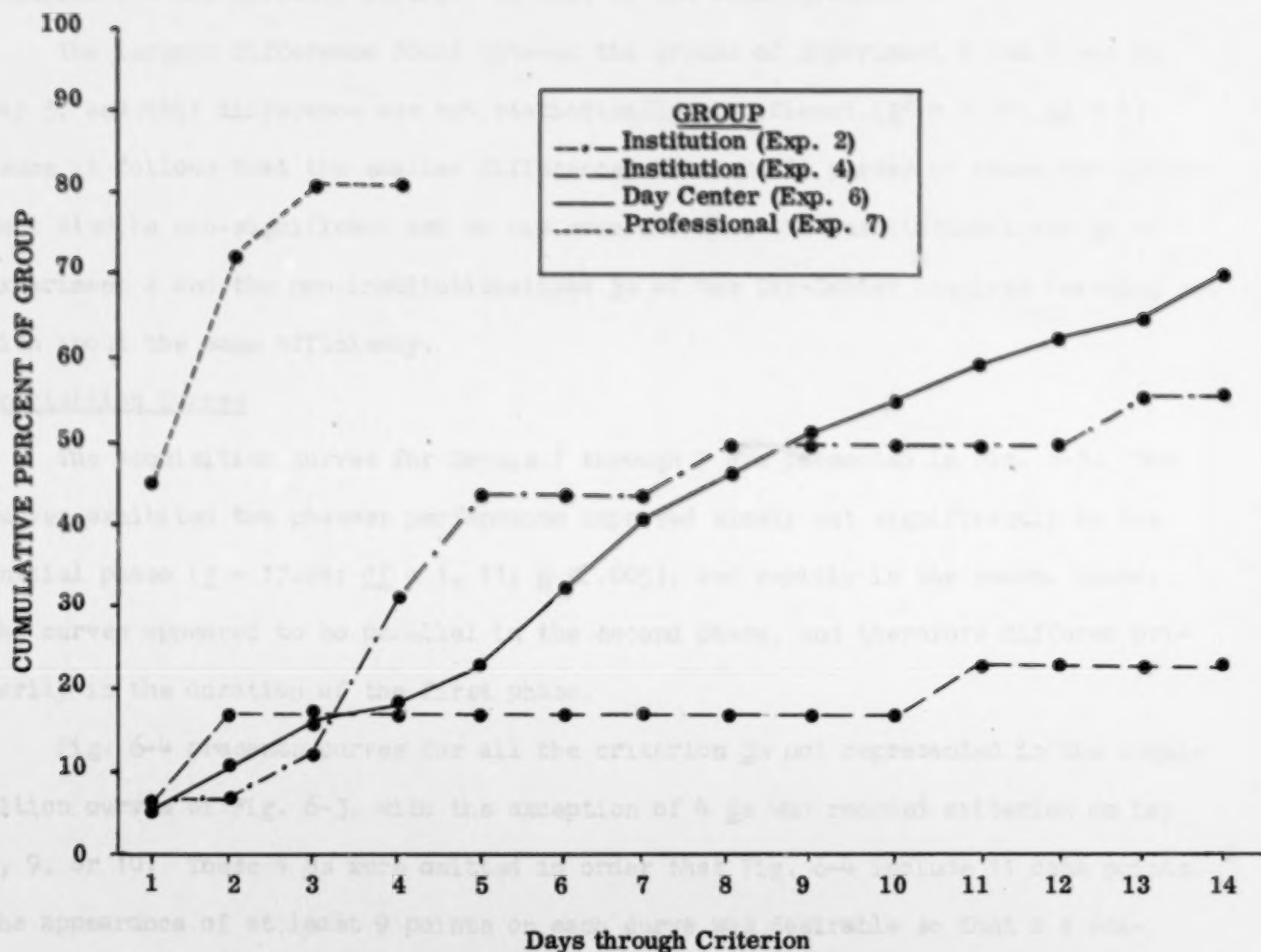


Fig. 6-2 Cumulative percentage of group reaching criterion as a function of days of training in institutionalized, day-center, and professional groups.

of Experiments 4 and 6 were already clearly evident by Day 14. Examination of the figure shows that (a) the performance of the professional group was markedly superior to that of the other groups; (b) there seems to have been little difference between the performance of the institutionalized group of Experiment 2 and the day-center group (Experiment 6); and (c) the performance of the institutionalized group of Experiment 4 was markedly inferior to that of the other groups.

The largest difference found between the groups of Experiment 2 and 6 was on Day 5, and this difference was not statistically significant ($\chi^2 = 1.34$; $df = 1$). Hence it follows that the smaller differences between the curves of these two groups must also be non-significant and we may conclude that the institutionalized Ss of Experiment 2 and the non-institutionalized Ss of the Day-Center acquired learning set with about the same efficiency.

Acquisition Curves

The acquisition curves for Groups 1 through 7 are presented in Fig. 6-3. The curves exhibited two phases; performance improved slowly but significantly in the initial phase ($F = 17.94$; $df = 1, 11$; $p < .005$), and rapidly in the second phase. The curves appeared to be parallel in the second phase, and therefore differed primarily in the duration of the first phase.

Fig. 6-4 presents curves for all the criterion Ss not represented in the acquisition curves of Fig. 6-3, with the exception of 4 Ss who reached criterion on Day 8, 9, or 10. These 4 Ss were omitted in order that Fig. 6-4 include 11 data points. The appearance of at least 9 points on each curve was desirable so that a comparison could be made with the acquisition curves of the preschool group, the only other group tested which included Ss who required 9 days to achieve criterion.

The Ss in Fig. 6-4 were arbitrarily divided into two groups: those who required 11 to 18 days to attain criterion, and those who required 21 to 37 days to criterion. Examination of the curves for these two groups suggests that they are essentially identical. Points A and B on the baseline are Vincentized represen-

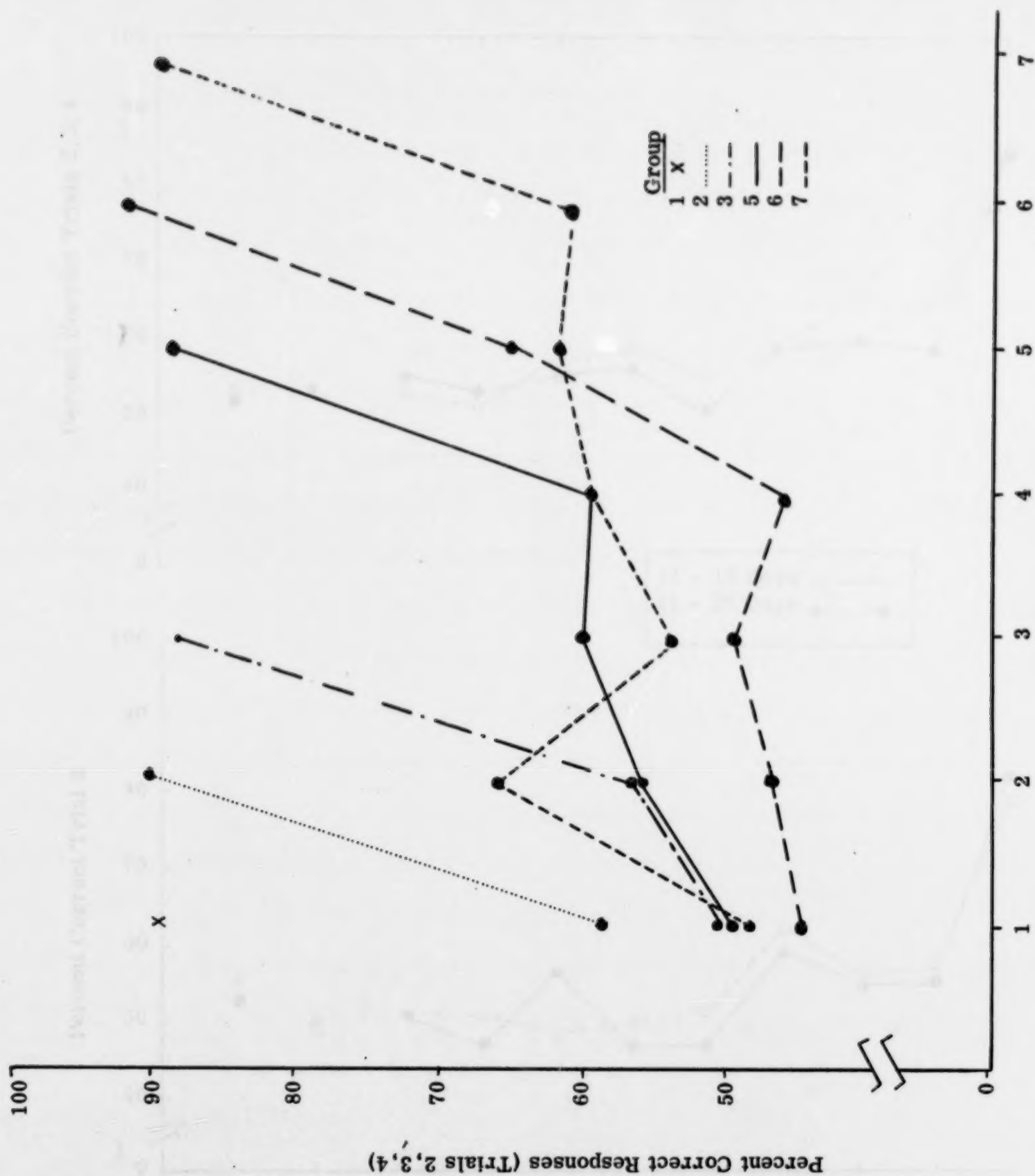


Fig. 6-3. Learning Set Performance as a Function of Days to

10 - Problem Blocks

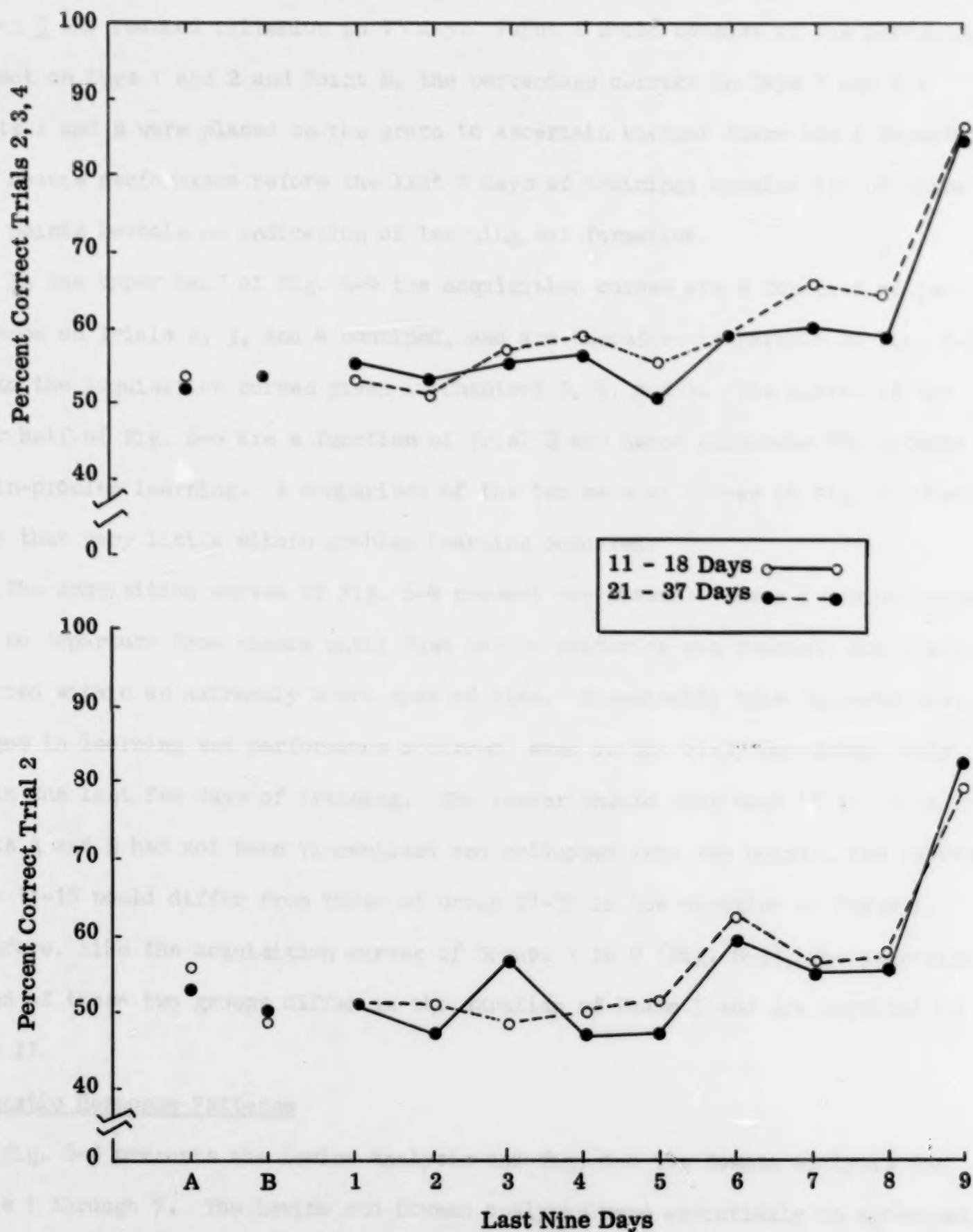


Fig. 6-4 Acquisition curves for the last 9 days of training for Ss requiring 11 or more days to achieve learning set criterion. Points A and B are Vincentized.

tations of the first and last halves of training, excluding the last 9 days (e.g. for an S who reached criterion in 13 days, Point A would consist of the percentage correct on Days 1 and 2 and Point B, the percentage correct on Days 3 and 4). Points A and B were placed on the graph to ascertain whether there was a departure from chance performance before the last 9 days of training; examination of these two data points reveals no indication of learning set formation.

In the upper half of Fig. 6-4 the acquisition curves are a function of performance on Trials 2, 3, and 4 combined, and are therefore comparable to Fig. 6-3 and to the acquisition curves given in Chapters 3, 4, and 5. The curves of the lower half of Fig. 6-4 are a function of Trial 2 and hence eliminate the effects of within-problem learning. A comparison of the two sets of curves in Fig. 6-4 indicates that very little within-problem learning occurred.

The acquisition curves of Fig. 6-4 present two phases: Phase I was prolonged, with no departure from chance until just before criterion was reached; and Phase II occurred within an extremely short span of time. Essentially this suggests that changes in learning set performance occurred, even in the 21-37 Day Group, only within the last few days of training. The reader should note that if the data for Points A and B had not been Vincentized and collapsed into two points, the curves for Group 11-18 would differ from those of Group 21-37 in the duration of Phase I. Therefore, like the acquisition curves of Groups 1 to 7 (Fig. 6-3), the acquisition curves of these two groups differ in the duration of Phase I and are parallel in Phase II.

Systematic Response Patterns

Fig. 6-5 presents the Levine analysis and Fig. 6-6 the Bowman analysis for Groups 1 through 7. The Levine and Bowman analyses were essentially in agreement, although certain information was provided by each analysis that was not apparent in the other. In the Day 1 group, only the problem solution, H_1 , was evidenced.

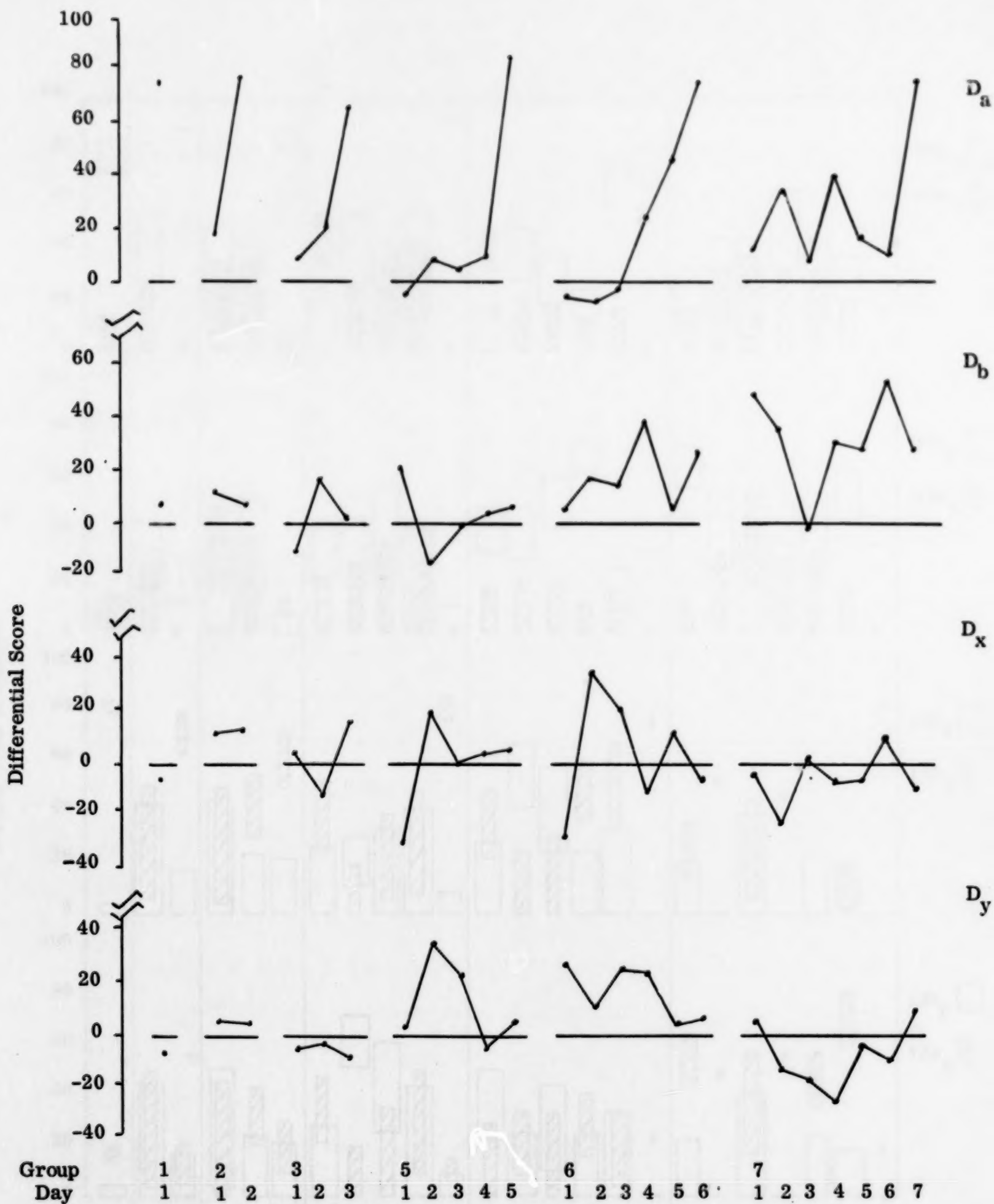


Fig. 6-5. Differential Scores as a Function of 10 - Problem Blocks for Aged Groups 1-7

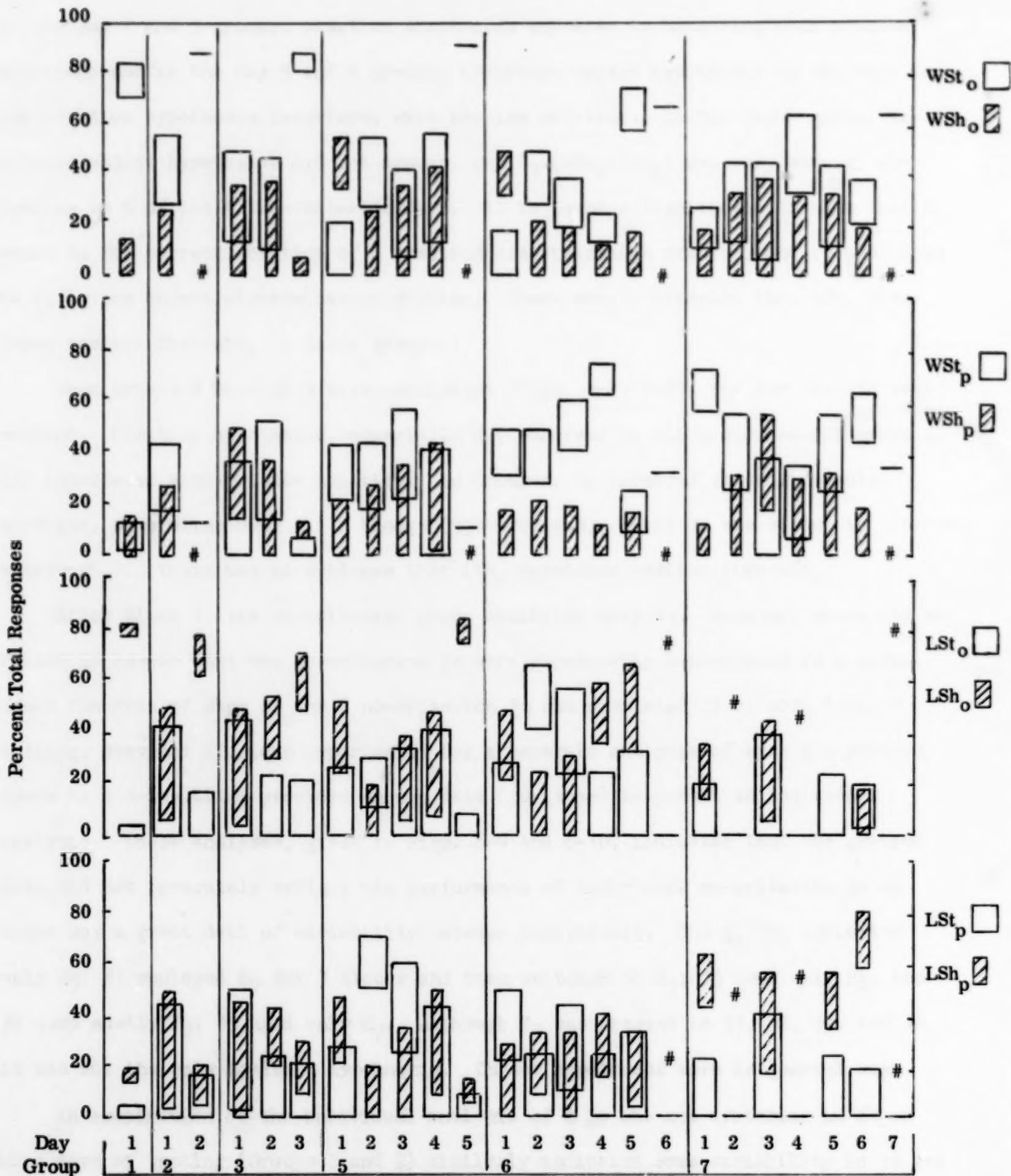


Fig. 6-6. Strategies in the Aged (Groups 1-7)

— an interval of zero width for a stay strategy
an interval of zero width for a shift strategy

In the Day 2 and 3 groups, position strategies appeared to interfere with problem solution; and in the Day 5 and 6 groups, incorrect object hypothesis in addition to the position hypotheses interfered with problem solution. In the Day 7 group, incorrect object hypotheses did not appear, but H_3 (WSt_p - LSh_p) was very strong, appearing on 4 of the 6 pre-criterion days. It is perhaps significant to note that H_3 would be the correct solution of a position discrimination problem, and is analogous to H_1 in the object discrimination problem. There was no evidence that LSh_o developed earlier than WSt_o in these groups.

When Groups A through E were considered (Figs. 6-7, 6-8), similar results were evident. Position hypotheses, especially H_3 , occurred in all groups except Group A, and interfered with problem solution. In Group E, H_8 appeared in considerable strength, persisting over all 7 blocks (350 problems), while H_3 was strong in Blocks 4 through 7. There was no evidence that LSh_o developed earlier than WSt_o .

After Block 1, the no-criterion group exhibited only H_3 . However, there was no reason to assume that the no-criterion S s were necessarily homogeneous as a group. Hence the data of each of the 7 no-criterion S s who completed 25 or more days of testing, provided a unique opportunity for a separate analysis of each S 's performance as a 5-day block provided enough data (50 items) to permit an individual analysis. These analyses, given in Figs. 6-9 and 6-10, indicated that the grouped data did not accurately reflect the performance of individual no-criterion S s as there was a great deal of variability between individuals. One S , #4, exhibited only H_3 ; #1 employed H_7 for 3 blocks and then switched to H_3 ; #5 used only H_8 , and #2 used mostly H_8 ; #3 used only H_7 . Although H_3 was present in #1, #2, #4, and #6, it was not the only dominant hypothesis. Object hypotheses were in general weak.

An examination of the individual analysis of 8 S s who met criterion in 24 or more days of testing (Groups D and E) similarly indicated some variability in H s and strategies employed (See Figs. 6-11 and 6-12). The group analysis for Groups D and E

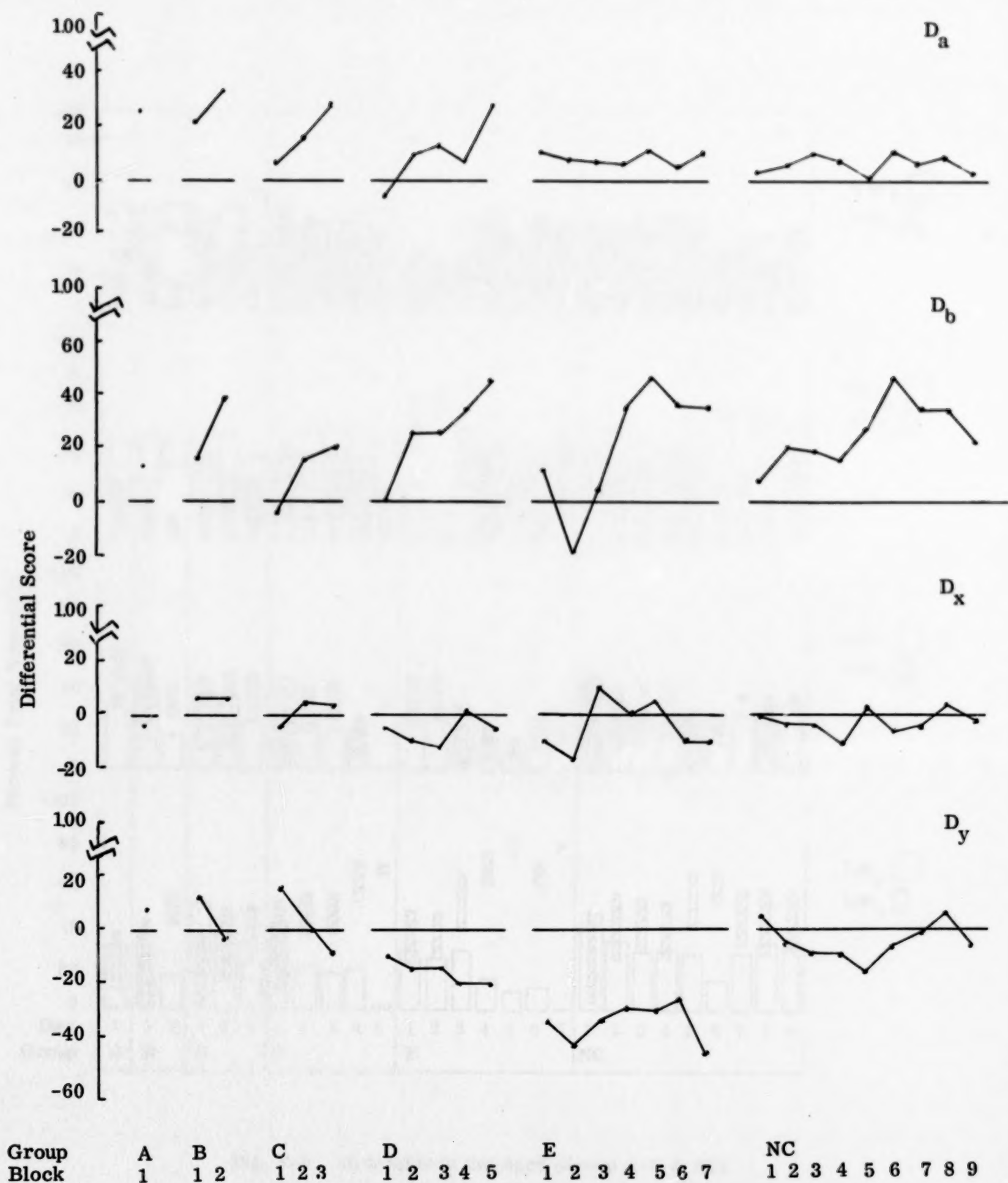


Fig. 6-7. Differential Scores as a Function of 50-Problem Blocks for Groups A - E and the Non-Criterion Group

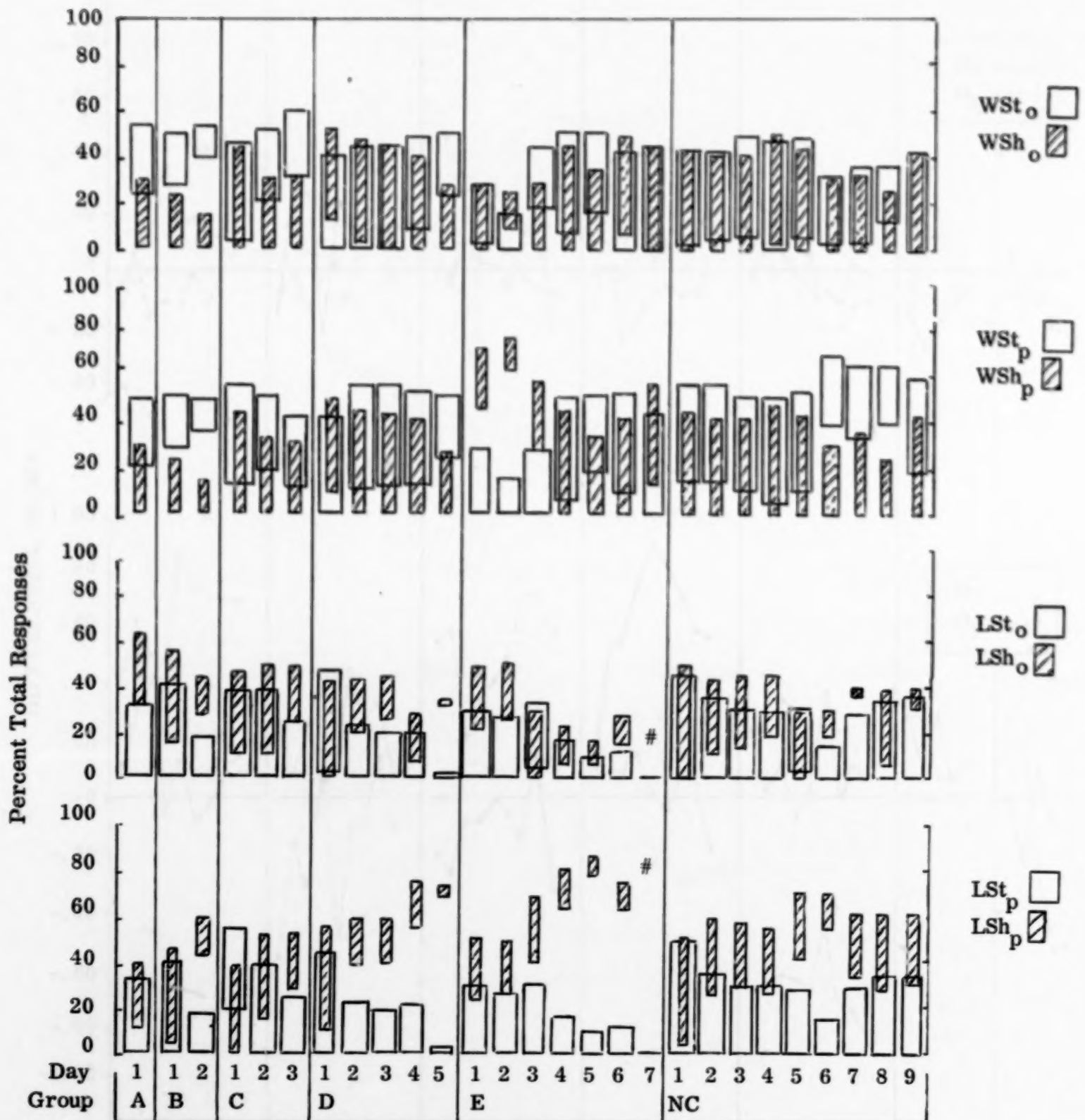


Fig. 6-8. Strategies in the Aged (Group A-E & NC)

— an interval of zero width for a stay strategy

an interval of zero width for a shift strategy

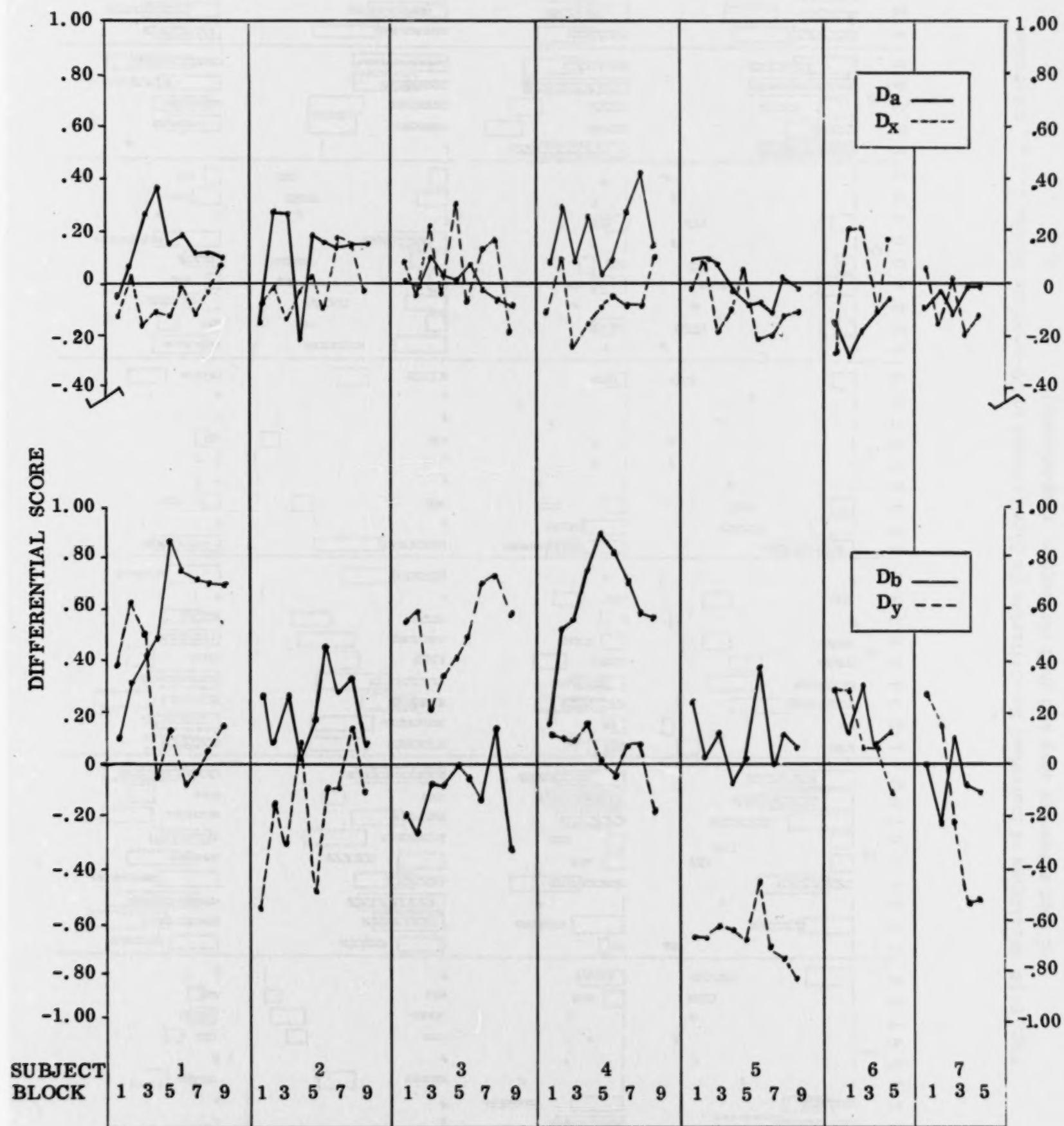


Fig. 6-9 Individual Curves: Differential scores in 50-problem blocks

Non-Criterion $\bar{S}_s$ (Aged Group)

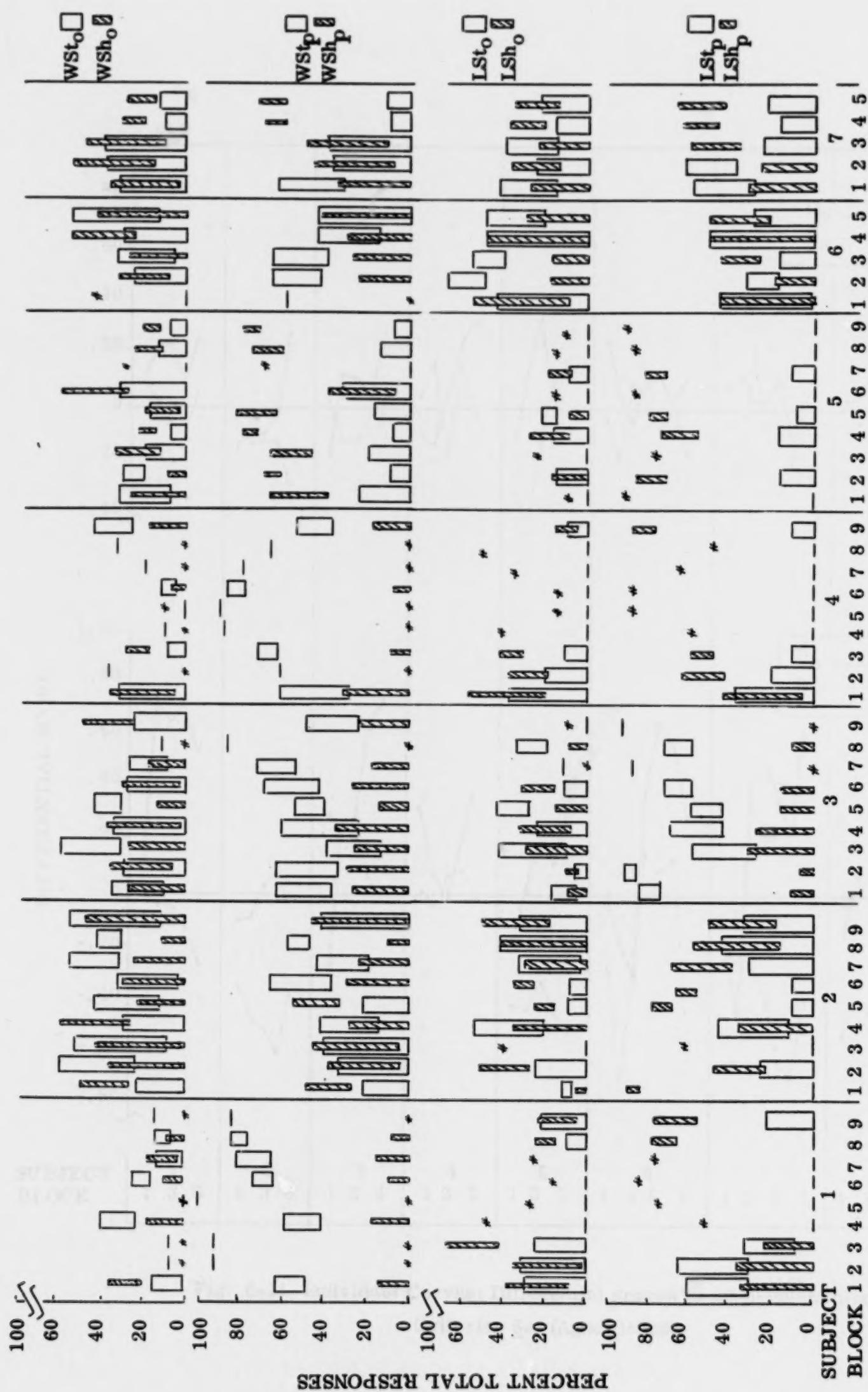


Fig. 6-10 Strategies of Individual No-Criterion Ss (Aged Group) in 50-problem blocks (—, #, intervals of zero range for stay and shift strategies, respectively).

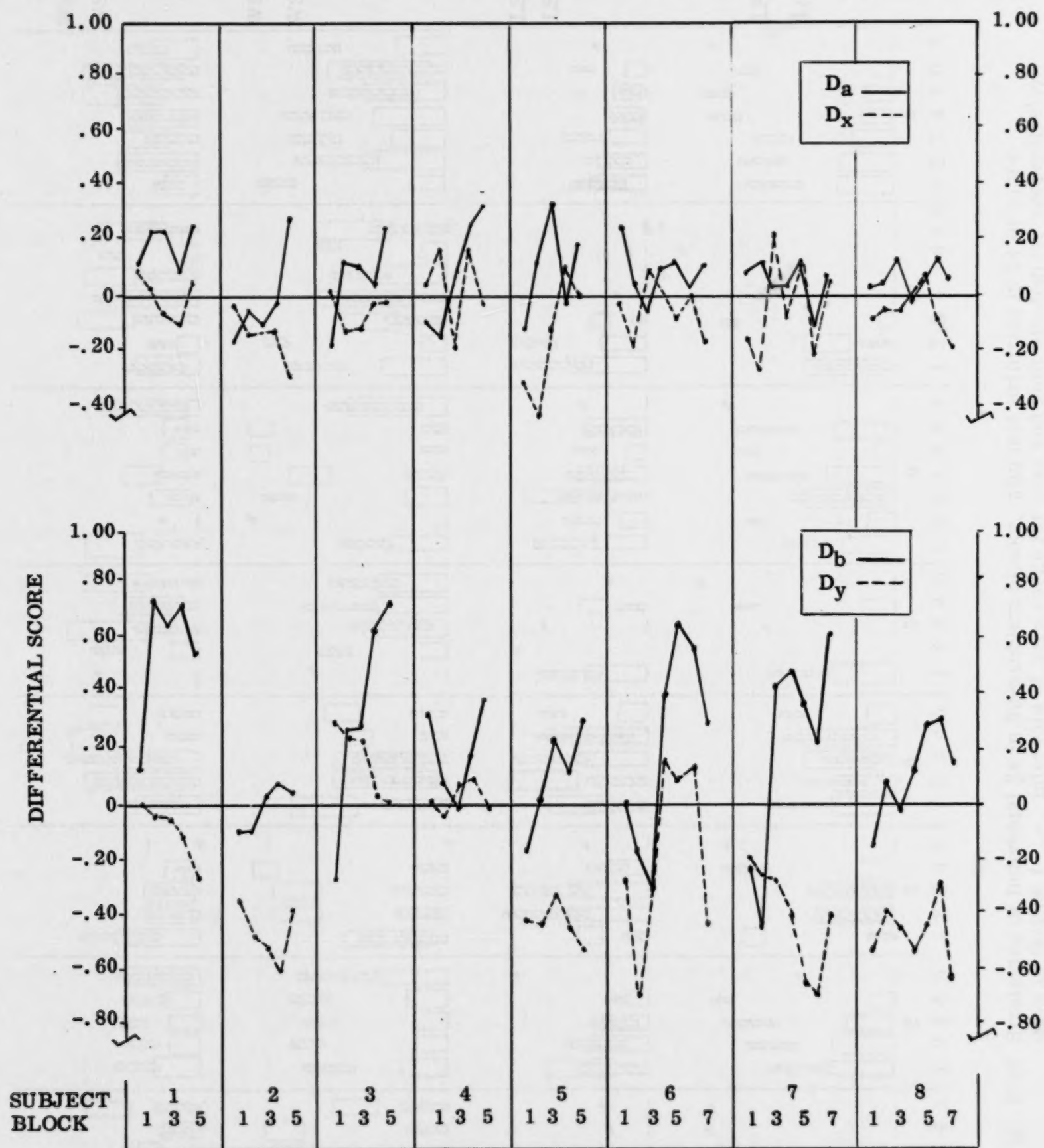


Fig. 6-11 Individual Curves: Differential scores in 50-problem blocks
Criterion S_s (Aged Group)

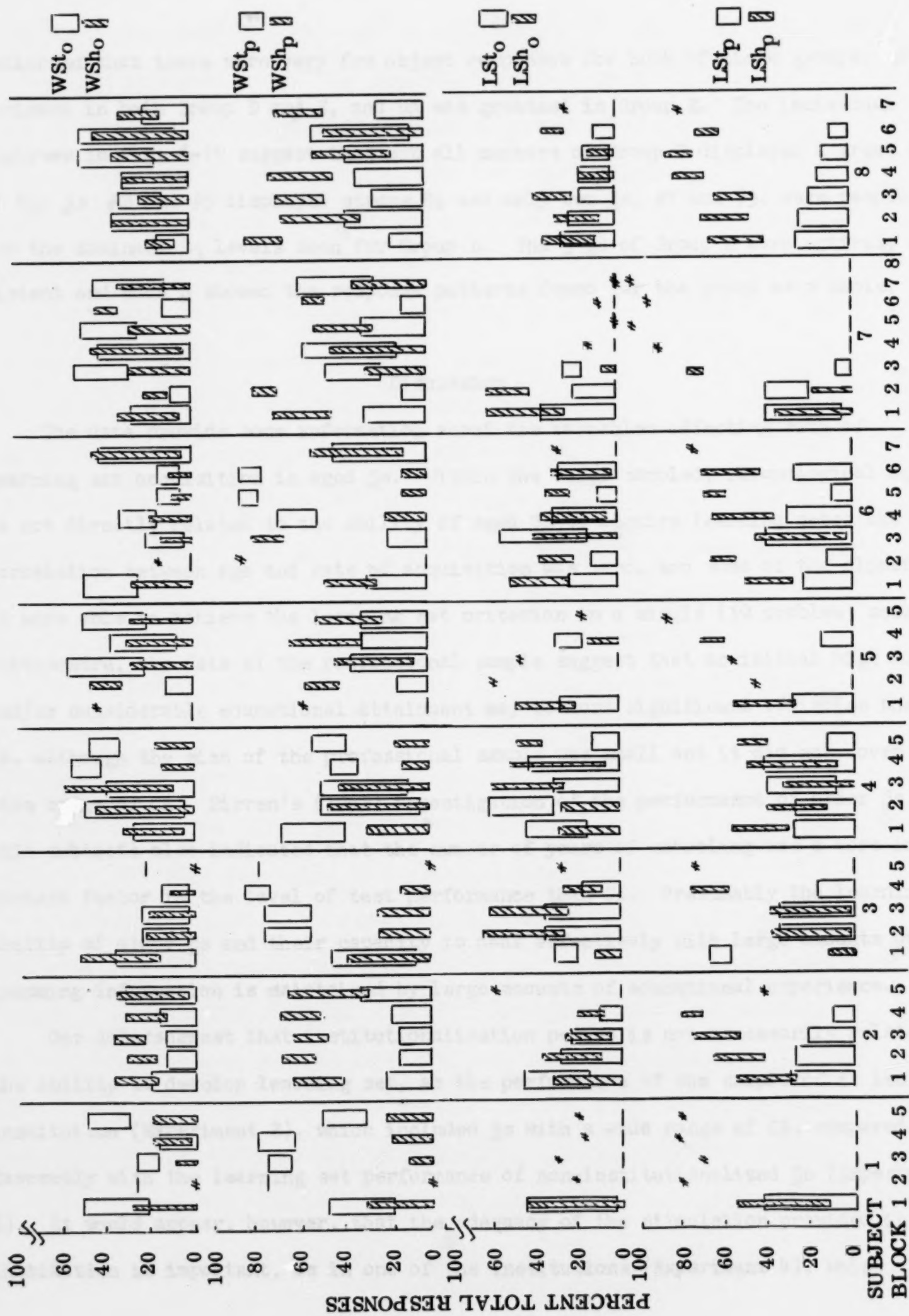


Fig. 6-12 Strategies of Individual Ss in 50-problem blocks, who met criterion in 24 or more days of testing (-, *, intervals of zero range for stay and shift strategies, respectively).

indicated that there were very few object responses for both of these groups. H_3 was dominant in both Group D and E, and H_8 was greatest in Group E. The individual analyses in Fig. 6-11 suggest that not all members of Group D displayed a great deal of H_3 ; S_s #2 and #5 displayed strong H_4 and only two S_s , #1 and #3, were responsible for the dominant H_3 levels seen for Group D. The 3 S_s of Group E were entirely consistent and each S showed the response patterns found for the group as a whole.

Discussion

The data provide some information about the variables affecting rate of learning set acquisition in aged S_s . Within the range sampled, chronological age is not directly related to the ability of aged S_s to acquire learning sets; the correlation between age and rate of acquisition was zero, and some of the oldest S_s were able to achieve the learning set criterion in a single (10 problem) session. Furthermore, the data of the professional sample suggest that an initial high IQ and/or considerable educational attainment may be more significant variables than CA, although the size of the professional sample was small and it did not cover a wide range of CA. Birren's (1963) investigation of the performance of older S_s on WAIS subtests also indicated that the number of years of schooling was a more important factor in the level of test performance than CA. Presumably the learning ability of older S_s and their capacity to deal effectively with large amounts of incoming information is maintained by large amounts of educational experience.

Our data suggest that institutionalization per se is not necessarily related to the ability to develop learning set, as the performance of the sample of at least one institution (Experiment 2), which included S_s with a wide range of CA, compared favorably with the learning set performance of non-institutionalized S_s (Experiment 6). It would appear, however, that the adequacy of the stimulation provided in an institution is important, as in one of the institutions (Experiment 4), which

appeared to provide inadequate stimulation, learning set acquisition was less efficient. (The fact that indigent Ss were included in Experiment 4 may also be relevant; indigence itself may engender a psychological state detrimental to learning or reflect some longstanding characteristic of apathy.) The superiority of the professional sample may well be due not only to their greater educational attainment, but more importantly to their continuing to seek and maintain a high level of stimulation.

Even though some of the aged Ss were able to achieve the learning set criterion in a single session, most were considerably slower. The slow rate of learning set acquisition is consistent with the data of other investigations of complex learning in older Ss (e.g. Botwinick et al., 1958). It is worth emphasizing that the learning set task is self-paced in that it allows S practically unlimited time to study the stimuli and make a response, and hence the deficit in learning set acquisition in the aged Ss, relative to younger Ss, is not the result of pressure from a timed or paced condition.

The response patterns visible in the aged group were predominantly position hypotheses rather than object hypotheses, and strong position habits persisted through prolonged periods of training. H_3 was especially prominent in many of the groups, indicating that the Ss were sensitive to reward contingencies, but were responding to irrelevant cues.

A number of investigators have shown that older Ss have difficulty in shifting set or alternating from one operation to another (e.g. Botwinick, 1959; Botwinick, et al., 1958). Singer (1963) has concluded that aged persons, except very healthy ones, exhibit impulsive test behavior, combined with marked drift from topic to topic, but with perseveration of ideas within the drift. These observations are consistent with our data on response patterns.

There are several kinds of problems inherent in testing older Ss which make it

difficult to interpret the results unambiguously. One problem is the difficulty in applying conventional learning set procedures. The introductory procedures which were applied to younger Ss had to be considerably elaborated for older Ss. Nursery school, fifth-grade, and college Ss who were told that they would be tested were agreeable or at least tolerant of the situation, but immediate defensive reactions occurred in the older Ss, and even the professional Ss had to be approached with circumspection. The aged Ss were moved toward accepting the test situation by reassurances that they could withdraw if the initial sessions were found unpleasant.

Skill in human relations had to be developed to make it difficult for the older S to refuse to continue, and became such a critical factor that testers had to be carefully selected and very slowly introduced to the older groups. The personality of the tester was important, and emphasis was placed on being tactful and yet sociable. The testing situation had to be firmly structured to avoid extraneous discussion during the testing trials and to postpone the social situation until the testing was completed. There was a constant and persistent questioning to be parried, as Ss repeatedly questioned how they were doing in relation to the group, what the task measured, and whether it indicated that they were "still normal".

One of the most difficult problems was that of controlling the leaking of information from individuals to others in their group. The older Ss, perhaps driven by anxiety, appear to have a strong need for feedback, so that constant reminders were necessary to prevent them from discussing and comparing their experiences. Information control would probably be a problem in any group that resided together but there was an intense surveyance and persistent questioning about the details of our procedures that was noteworthy.

Another difficulty intrinsic in the problem of studying learning processes in an aged group is that of selection of Ss. We wanted to test only individuals who were free of medical and mental disturbances, but had to rely on the administrators

of the institutions to select our Ss. In several of the institutions detailed medical records were available, but in others the administrators had to draw on their experience with each resident to form a basis for selection. There is only one study in the literature that selected a group of older Ss on the basis of extensive preliminary medical testing and interviews to find well-functioning aged Ss and to eliminate those with some physical disability (Birren, *et al.*, 1963). However, the problems of limited stimulation, defensive reactions, indigence, etc., may be considered characteristic of old age, since the relative frequencies of these problems in aged populations are presumably greater than in the population as a whole, so that selecting active, healthy, medically-certified Ss free of problems may create a biased sample.

A third difficulty is that, as in any learning study, motivation must be controlled, and this is an especially difficult variable to manipulate in an older S. A correct response was indicated in the younger groups by finding a candy in the reward-well under the correct object. This incentive was unsuitable for older Ss, many of whom had digestive difficulties or were limited in caloric intake. Our initial use of buttons as token rewards was perceived as "childish" and offended the dignity of some Ss. It was only when pennies were introduced as rewards that a high level of motivation was induced; but the sum of money involved, although small, became much too salient in some cases, and there was a strong suggestion in Experiment 5 that the Ss were driven to maximize the monetary reward with a consequent contamination of the subject pool and spurious test results.

Summary

Seven samples of aged Ss were given learning set training; usable data were secured from several institutions, a golden-age club and a group of retired college professors. 56 Ss who attained criterion and a group of 21 no-criterion Ss were

selected for data analysis.

No correlation was found between age and number of days to reach criterion, but the aged group as a whole was exceedingly inefficient in developing learning set. The performance of a small sample of retired professional Ss was superior to that of the group as a whole; in addition to their considerable educational background, the retired professional Ss undoubtedly had a higher initial IQ and a continued exposure to stimulation. No difference was found between the scores of institutionalized Ss, where the institution environment was judged to be stimulating, and those of non-institutionalized Ss who resided in their own homes and attended the activities of a golden-age club. The learning of Ss in a second institution was markedly inferior to that of the other institution and may reflect the detrimental effect of a non-stimulating institutional environment and/or the fact that many of the Ss in the second institution were indigent.

The acquisition curves of all criterion-reference groups exhibited two phases with but little improvement manifest in Phase I; the duration of Phase I varied from zero to 30 days or more. A sharp rise in Phase II was similar in all groups. The response patterns of the aged groups were characterized by perseveration of position responses through prolonged periods of training.

Chapter 7

Comparisons Across Age Levels

Comparisons of the data of the four age levels sampled in the experiments reported in the previous chapters can lead to some conclusions about the effects of developmental variables on learning set formation, but the tentative nature of the conclusions must be emphasized because the groups differed along many dimensions in addition to age. These differences, and the necessary procedural differences, are discussed below.

Method

Subjects. A wide range of socio-economic levels was represented at each age level. The samples included 53 preschool children obtained from 3 different nursery schools (described in Chapter 3); 53 fifth-grade children from a rural and a suburban school district (Chapter 4); 57 college freshmen (Chapter 5); and 73 older people ranging in age from 61 to 97 years, obtained from 2 institutions for the aged and a Golden Age club (Experiments 2, 4, and 6, Chapter 6).

Apparatus and Materials. The apparatus and materials were identical in all of the experiments, except that different rewards were used. For the preschool, fifth-grade, and college groups, M & M chocolate candies were used as rewards; and for the aged groups pennies were used as rewards.

Procedure. The basic procedure was the same in all of the experiments, but the details of procedure differed in three ways across groups. First, preliminary procedures designed to establish rapport with S were used only with the preschool and aged groups. With the aged groups especially elaborate introductory procedures were required to elicit a cooperative atmosphere. Second, the preschool and aged Ss were given 10 problems per day, but the fifth-grade and college groups received all of

their training in a single session. For the preschool Ss the sessions were continued until criterion was reached; for the aged Ss the sessions were continued until criterion was reached, or until S had received a fixed number of sessions, or until S terminated the sessions; and for the fifth-grade and college groups the single session was continued to a maximum of 30 problems. Third, the preschool children were tested 5 days a week; all aged groups were tested 7 days a week, except the non-institutionalized Ss at the day center, who were tested 2 or 3 times a week, on the days they attended the center; and as already noted, the fifth-grade and college groups were tested in a single session.

Results

Rate of Acquisition. The median number of problems required to attain the learning set criterion was 20.4 for the preschool group, 10.8 for the fifth-grade group, 6.7 for the college group, and about 120 for the combined age groups.

Fig. 7-1 presents the cumulative percentage of each age group reaching criterion on each day of testing. It is readily apparent that the aged group was inferior to the younger groups.¹ The preschool, fifth-grade, and college groups differed significantly from each other ($\chi^2 = 25.00$; $p < .001$).

The 11 professional Ss in the aged sample (Experiment 7, Chapter 6) were given a maximum of 4 days of testing; 5 of the professional Ss achieved criterion on Day 1, 3 on Day 2, 1 on Day 3, and none on Day 4. (The corresponding cumulative percentages, comparable to the values plotted in Fig. 7-1, were Block 1, 45.5; Block 2, 72.7; Blocks 3 and 4, 81.8.) The professional sample therefore appears not to have performed as well as the college students sampled (Chapter 5), but several consi-

¹This was not true of the retired professional Ss (Exp. 7, Chapter 6).

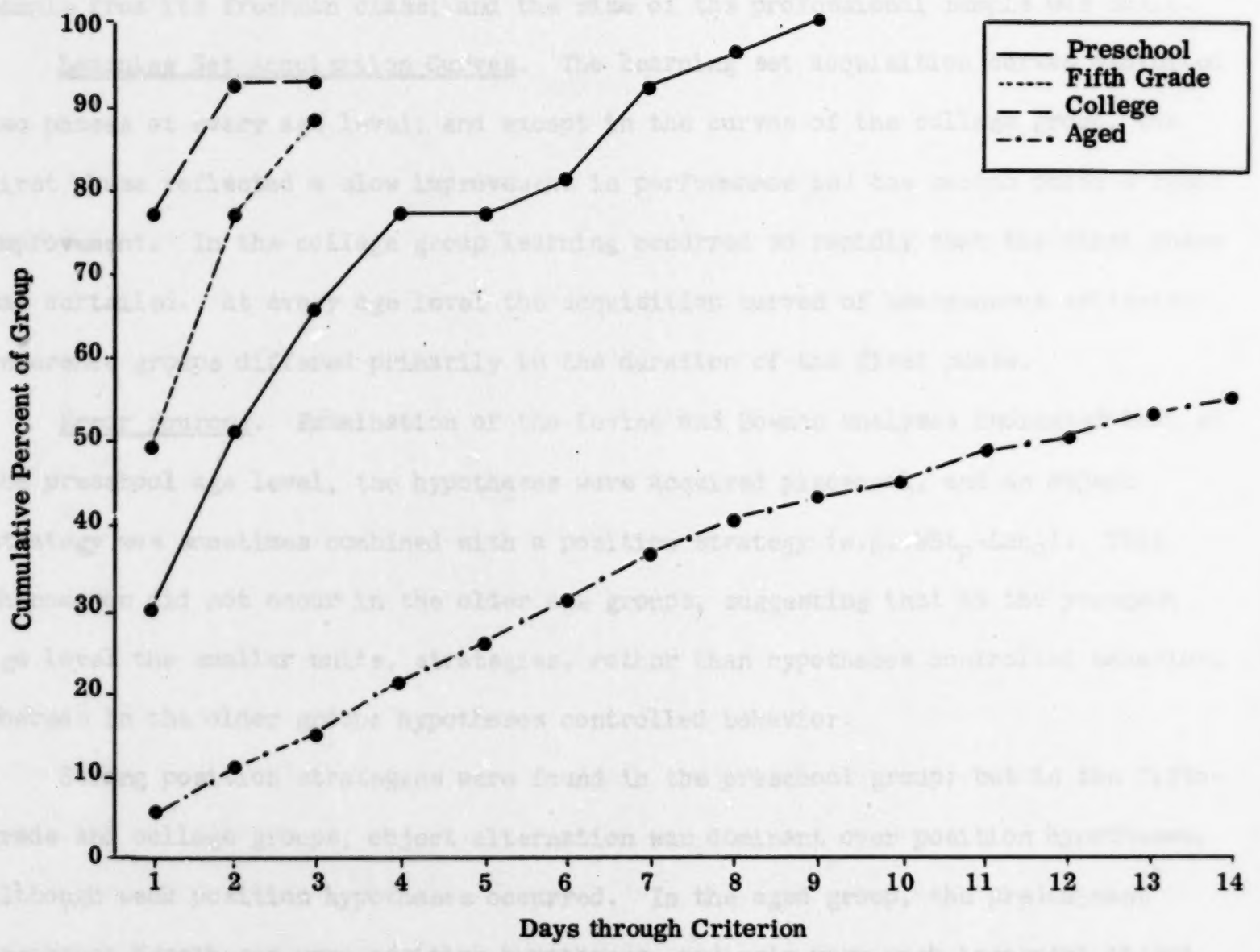


Fig. 7-1 Cumulative percentage of age groups reaching criterion on each day of testing.

derations make the validity of the comparison between these two groups doubtful. The professional sample received distributed practice (10 problems per day), and the college sample received massed practice (all problems in a single session); the educational achievement of the professional sample was considerably greater than that of the college sample; the professional group was probably a superior sample in its freshman class, but the college group was probably a more representative sample from its freshman class; and the size of the professional sample was small.

Learning Set Acquisition Curves. The learning set acquisition curves exhibited two phases at every age level; and except in the curves of the college group, the first phase reflected a slow improvement in performance and the second phase a rapid improvement. In the college group learning occurred so rapidly that the first phase was curtailed. At every age level the acquisition curves of homogeneous criterion-reference groups differed primarily in the duration of the first phase.

Error Sources. Examination of the Levine and Bowman analyses indicated that at the preschool age level, the hypotheses were acquired piecemeal, and an object strategy was sometimes combined with a position strategy (e.g. WSt_p-LSh_o). This phenomenon did not occur in the older age groups, suggesting that at the youngest age level the smaller units, strategies, rather than hypotheses controlled behavior, whereas in the older groups hypotheses controlled behavior.

Strong position strategies were found in the preschool group; but in the fifth-grade and college groups, object alternation was dominant over position hypotheses, although weak position hypotheses occurred. In the aged group, the predominant incorrect hypotheses were position hypotheses, and only very weak incorrect object hypotheses occurred. (See footnote 1 on p. 84.)

In the preschool, fifth-grade, and college groups, the lose-shift component of the correct hypothesis developed earlier than the win-stay component, suggesting that a nonreward provided more information than a reward. In the aged group, on the other

hand, there was no evidence that LSh₀ developed any earlier than WSt₀.

The groups appeared to differ in the variety and persistence of incorrect hypotheses and strategies. The youngest and oldest groups tried out a greater variety of strategies than the others, but the incorrect hypotheses were most persistent in the aged group. The performance curves of the aged Ss who required prolonged training to acquire the learning set (11 or more days) displayed improvement only late in training (the last 5 or 6 days).

Discussion

The acquisition curves of all groups exhibited two phases. Early in the first phase performance remains approximately at the chance level, and then a slow rise occurs. The rise is more marked in acquisition curves plotted as a function of Trials 2, 3, and 4 combined than in acquisition curves plotted as a function of Trial 2, because the former include the improvement in performance due to within-problem learning.

In the curves of the preschool and fifth-grade groups, the chance level in the first phase was maintained only briefly. There was no departure from chance performance in Phase I visible in the college group as the transition to Phase II occurred very rapidly. In the curves of the aged samples the chance level of performance was prolonged; for many of the older Ss this prolongation extended through many weeks of training.

The response pattern analyses for each of the age groups indicated the incorrect response patterns used during the period of chance level performance. Performance remains at the chance level as long as S is utilizing an incorrect response pattern, except H₂ (WSh₀-LSt₀) which yields zero percent correct. As S shifts from one incorrect response pattern to another, his performance remains at the chance level, but he may be moving closer toward the correct solution since there is in the Levine

system a limited number of incorrect hypotheses. The age differences in the duration of the chance level of performance in Phase I reflect the number of incorrect hypotheses explored by S and the length of time spent on each. The aged Ss responded persistently to position, and even after they began to respond to objects, seem to have persisted longer in incorrect object hypotheses than the younger groups. The learning deficit in the preschool Ss appears to be related to their tendency to combine object and position strategies.

The chance level of performance in Phase I occurs during a period in which S is either attending to irrelevant cues (as in position hypotheses), or ignoring the reward contingencies (as in object preference and object alternation). When S begins to attend to the relevant cues and the reward contingencies, his performance level begins to improve as he begins to practice the correct hypothesis. It is important to emphasize that in the homogeneous criterion-reference groups of the four age levels sampled, the major difference appeared in the duration of Phase I. Once the transition to Phase II occurred, all of the criterion-reference curves, regardless of age group, rose rapidly. There was very little difference in the duration and appearance of the Phase II curves.

The finding that the fifth-grade group developed learning set more rapidly than the preschool group, and was in turn surpassed by the college students, suggests that a gradient in experience with similar or related tasks is involved. The aged professional sample may be thought of as falling on this gradient, but the other aged groups do not seem to fit, although a few Ss in each of the aged samples did display rapid and efficient learning set formation. It is reasonable to assume that even if age differences among the younger groups reflect transfer effects from general experience, the inferiority of the nonprofessional aged groups results from other factors.

The extent that the behavior of older Ss is characterized by perseveration of

response, difficulty in shifting sets, reduced physiological activity represented by the slowing of responses, and difficulty in the manipulation of symbols (see discussion, Chapter 6) suggests that a hypothesis of organic deterioration may account in part for the lack of efficiency in learning set formation. A source of interference may be related to a social deprivation dimension (Zigler, 1962). As noted in Chapter 6, some aged Ss seemed easily distracted from the task, preferring to socialize with E. Attention is probably devoted not only to irrelevant object cues, but also away from task orientation, resulting in decreased sensitivity to the reward contingencies. Factors of indigence, time spent in an impoverished institutional environment (Chapter 6), and poor health are also relevant. As the aged samples differed along a variety of dimensions from the other age groups tested, such as socio-economic class, educational attainment, motivational level and possibly innate mental ability, it is difficult to attribute the poorer learning set performance to the effect of age per se. To the extent that so many of the aged Ss did attain criterion, we must conclude that retention processes are still functioning.

Summary

A strong age trend in rate of learning set acquisition was obtained. Speed of acquisition increased from preschool through college, but was markedly slower in the aged group than in the younger groups. The shape of the learning set acquisition curve was about the same for every age level, exhibiting two phases. Differences among the homogeneous sub-groups within each age level were primarily in the duration of the first phase.

The average speed of learning set acquisition in the different groups was inversely related to the average strength of position strategies. Position strategies were predominant in the aged group, strong in the preschool group, and

weak in the fifth-grade and college groups. Incorrect object strategies were relatively infrequent.

In all of the groups except the aged, LSh₀ developed earlier in training than WSt₀, suggesting that a nonreward provided more information than a reward in the younger groups.

The variety and persistence of incorrect hypotheses and strategies appeared to be greater in the youngest and oldest groups than in the others, and greater in the oldest than in the youngest group.

Chapter 8

Discussion

Conclusions and Implications

The present study is unique in that (a) it is the first to compare learning set formation in human ss of widely separated age groups, using training procedures which approximated very closely the procedures employed in animal studies, (b) it is the first report of learning set in the aged, and (c) it is the first study to apply and compare the efficacy of the Harlow error factor analysis and the Bowman and Levine methods of analysis. An attempt is made in this section to relate our findings to the data available from other learning set studies, although such comparisons must be tentative because of differences between studies in the learning set procedures applied.

Learning Set Acquisition Curves

Our study shows that the speed of acquisition of learning set varies with age, but the general shape of the acquisition curve is essentially the same at all four age levels sampled. At every age level the acquisition curves of the homogeneous (criterion-reference) subgroups exhibited two phases, with a period of chance level performance followed by a slow rise in Phase I (except in the fastest learning ss, whose curves lacked the slow rise), and in Phase II a period of rapid improvement which included the criterional performance. A search of the literature revealed that other investigators have under certain conditions obtained this type of curve; Reese (1963, p. 123-5) in an extended discussion of the learning set curve described the conditions under which two-phase curves have been found. A recent study by Harter (1964) on learning set in children found the two-phase curve in all homogeneous groups tested as well as in the majority of curves plotted for individual ss. We believe that the two-phase curve has considerable theoretical importance and would suggest that future studies of learning set be planned so that the curves of homogeneous groups can be examined.

Comparisons among the four age levels tested in the present study revealed that the major age differences were in the duration of Phase I, and especially in the duration of the period of chance level performance. The curves were strikingly similar and parallel in Phase II for all age groups.

Comparative studies of learning set formation in infra-human species have clearly demonstrated a relationship between phylogenetic status and learning set ability (Harlow, 1959), although studies on the gorilla and other great apes (Fischer, 1962; Hayes, Thompson, & Hayes, 1953; Rumbaugh & Rice, 1962), have not conclusively placed the great apes in relation to the other primates, mainly because very small numbers of Ss have been tested and the learning set procedures have not been equivalent. Human Ss can be tentatively compared with the rhesus monkeys; in a study using a learning set procedure identical to that of the present study, Levinson (1958) found that a group of naive rhesus monkeys required about 200 problems to reach a level of 90% correct Trial 2 responses. The preschool group reached this level in fewer than 50 problems. Although the speed of learning set formation in our aged sample was not markedly different from that of rhesus monkeys, the acquisition curves of the aged differed from the monkey curves. In general, the learning set acquisition curves of monkeys are ogival; the duration of the initial relatively flat portion of the curve depends on the difficulty of the problems, the amount of preliminary taming of the Ss, and other factors, but even after the curve rises above the chance level, there is a prolonged period of gradual improvement before criterion is attained (Harlow, 1959; Reese, 1964). In the aged, on the other hand, the period of improvement following chance level performance is relatively brief, and compared to the monkey curves, the rise to the criterional level is sharp. These findings must be regarded with caution; it is possible that the curves of a group of 3-year old monkeys carried to individual rather than group criterion and divided into homogeneous criterion-reference groups might be comparable to those described in the present study.

Rumbaugh & McQueeney (1963), investigating the formation of learning set in the smooth-brained squirrel monkey, found that learning set could be most efficiently developed by requiring Ss to solve each problem before progressing to the next; and Reese (in press) obtained similar results using this procedure with preschool children. Sterritt, Goodenough, & Harlow (1963) compared the learning set performance of animals required to solve each problem with that of a group of animals which received six trials per problem. They failed to demonstrate greater efficiency for the first group, probably because the learning criterion for individual problems was 20 correct of 25 successive trials, whereas 5 correct out of 6 would have been enough. Reese obtained in his study a median of 5.9 problems to learning set criterion for the problem solution group, which can be compared to the 20.4 problems to criterion in the 4-trial-per-problem group of the present study. It would be worth repeating these studies with a sample of aged Ss to ascertain if learning set acquisition would be facilitated under these conditions.

Systematic Response Patterns

Harlow Error Factors. Position responses are an essentially unimportant source of error in rhesus monkeys (Harlow, 1959; Warren & Sinha, 1959), but position preferences occur in Java monkeys (Schrier & Harlow, 1956), suggesting that there may be species differences. Among human Ss, position responses are more important sources of error in severely mentally retarded Ss than in high-grade defectives or in normal Ss, and more important in younger than in older normal children (see Reese, 1963). These responses were negligible in our fifth-grade and college groups, but were frequent in the preschool sample, and were a major source of error in the aged Ss. The position responses may be more primitive responses and hence present in the youngest and aged groups. Cue guided responses would appear when the position guided response is inhibited.

The occurrence of stimulus preferences in monkeys is related to the stage of learning set formation, decreasing as training progresses (Harlow, 1950, 1959), and is more common in younger monkeys than in mature animals (Harlow, 1959). This error may be more characteristic of mentally retarded children than of normal children, but the evidence is inconclusive (see Reese, 1963). We found negligible stimulus preference in all our groups.

Stimulus alternation apparently has a low probability of occurrence in monkeys, but in human Ss it occurs more frequently than stimulus preference. We found more stimulus alternation in the preschool and aged groups than in the fifth-grade and college samples.

Levine (personal communication) has shown that H_3 (WSt_p & LSh_p) is the same as Harlow's "differential cue" error factor (see p. 22 for definition). This error source persists longer in monkeys than most of the others (Harlow, 1959), and is stronger in experimentally naive monkeys than in experimentally sophisticated monkeys (Fitzgerald & Davis, 1960). The first-trial outcome does not affect the differential cue error in monkeys; it has about the same strength after a first-trial error as after an initial correct response. (Harlow & Warren, 1952). Ellis, Girardeau, and Pryer (1962) found little difference between normal children and mentally retarded Ss; the differential cue error was fairly strong in both groups. We found little of this error in the fifth-grade and college groups, but we found a strong differential cue error in the preschool Ss, and an even stronger one in the aged sample.

The response-shift error, according to one definition, is a greater frequency of errors following an initial correct response than following an initial error. Early in training, monkeys make more correct responses following a correct response on the first trial than following an error on the first trial (this tendency is opposite to the response-shift error); but later the trend is reversed and the response-shift error becomes strong--there are more

correct responses following an error than following a correct response on the first trial (see Reese, 1964). Several studies indicate that this kind of response-shift error is infrequent in children and mentally retarded Ss (Ellis, Girardeau, & Pryer, 1962; House & Zeaman, 1958; Stevenson and Weir, 1961). We found a strong response-shift error in the preschool group, but did not assess it in the older groups, since it is measured in Harlow's method of analysis, but not in Levine's and Bowman's. However, Bowman's model yields relevant information, provided by comparing the strengths of LSh_0 and WSt_0 . Since the lose-shift strategy was stronger than the win-shift strategy during most of the presolution period in all but the aged groups, it can be concluded that the response-shift error was present in all but the aged groups. Furthermore, the Bowman model suggests that the explanation of the response-shift error is to be sought, at least in human Ss, in analyses of strategies rather than as only a stimulus oriented response tendency. Thus inhibition can be seen as an active process leading to problem mastery and the lack of response shift in the aged groups can be seen as a failure of inhibition of the incorrect response and hence an important element in the prolongation of the pre-solution period.

A second definition describes response-shift as the number of errors following a series of correct responses when the initial response was correct, relative to the number of such errors when the initial response was incorrect. In monkeys this kind of response-shift is an important error factor, and is the most persistent error factor (Harlow, 1959). Harlow (1959) has suggested that it reflects a tendency of S to try out all objects in the discrimination situation. This kind of response-shift seems to be infrequent in human Ss (see Reese, 1963), and was not assessed in the present study.

Bowman and Levine Factors. Similar systematic response patterns were found at all age levels sampled in our study, but there were five age-related

differences worth noting. (a) There were more combinations of win and lose strategies in the preschool and aged groups than in the fifth-grade and college groups; (b) there were more position responses in the youngest and oldest groups than in the fifth-grade and college groups; (c) incorrect hypotheses were more persistent in the pre-school and aged, and particularly so in the latter, than in the fifth-grade and college samples; (d) the preschool, but not the fifth-grade, college, or aged Ss, combined WSt_p with LSh_o ; and (e) LSh_o clearly developed before WSt_o in all groups except the aged.

These findings suggest that the process of learning set formation is basically the same at all four age levels and involves the elimination of incorrect response patterns. The period of chance-level performance in Phase I of the acquisition curve apparently reflects the domination of incorrect strategies. The slow rise in Phase I results when the reward-contingent behavior combining LSh_o with a position strategy (WSt_p or WSh_p) occurs. The transition to Phase II takes place when the response patterns are completely determined by object strategies; the rapid improvement occurs when WSt_o becomes dominant in combination with the already present LSh_o behavior.

Differences in the duration of Phase I for the four age groups can be attributed to the differences exhibited in the response patterns. Since the preschool and aged groups exhibit more incorrect hypotheses, especially position hypotheses, and persist in them longer than the fifth-grade and college Ss, the chance level of performance must be more prolonged. It should be noted that in the aged group the striking endurance of incorrect hypotheses is associated with the prolongation of the period of chance level performance, but once this chance period ends, the performance of aged Ss is similar to that of the preschool and fifth grade Ss, exhibiting a similarly timed slow rise and a comparable Phase II. Although only the preschool Ss clearly exhibited the combination of LSh_o and a win position strategy, and hence their Phase I curves

rose more markedly, similar combinations must have occurred undetected in the fifth-grade and aged samples since their curves also exhibited the rise in Phase I.

Analysis of Age Trends

The relation between age and variations in strategy behavior remains to be explained, but it seems likely that not age but age-related variables must be invoked to account for this relation. Such variables include (a) developmental changes in cognitive abilities, (b) gradients of experience with similar or related tasks, and of educational attainment, (c) variations in adequacy of environmental stimulation, (d) intellectual differences, (e) developmental changes in attention processes, and (f) age-related motivational changes.

(a) Developmental changes in cognitive abilities. Harlow (1959, p. 504) pointed out that there is a growing body of data which indicates that learning set requires capacities that exceed those required for simple discrimination learning. The relevant data include differences in learning set performance between immature and adult ss and also differences between brain damaged and normal ss. Young children are limited in cognitive abilities, as these abilities are in a formative stage (Flavell, 1963; Luria, 1961), and deterioration of cognitive processes is a frequent concomitant of old age (whether this is due solely to an accumulation of disturbances in physical functions is still an unresolved question). A word of caution may be added; although the behavior of the aged appears in some aspects similar to that of children, it should not be implied that the underlying operations leading to their achievements are identical.

As children grow older, there is greater goal directedness, greater ability to focus on the problem, increased persistence in attempts to find a strategy, and their choices tend more to probability matching (Stevenson & Weir, 1959). There is also an increase in variability and an increasing search for pattern

and order (Crandall, Solomon, & Kellaway, 1961). In the aged, these processes change: there is less ability to alternate or shift from one set to another (Botwinick, Brinley, & Robbin, 1958), and perceptual-integrative abilities decline (Botwinick & Birren, 1963; Botwinick, Robbin & Brinley, 1959). There is difficulty in dealing effectively with large amounts of incoming information (Birren, 1963), difficulty in extinguishing or otherwise modifying materials already learned (Kay, 1959), and difficulty in manipulating materials in novel ways (Birren, Botwinick, Weiss, & Morrison, 1963).

As many of the aged population suffer some organic deterioration it may be that any cognitive deficit found can be attributed to this factor. While our aged Ss were selected to be free of known organicity, we cannot be sure that some was not present and responsible for the inefficiency displayed in learning-set formation. Supporting data from monkey studies indicate that animals with large neocortical lesions do not acquire learning set (Chow, 1954; Riopelle, Alper, Strong, & Ades, 1953) or are less efficient in forming learning set (Brush, et al., 1961; McDowell & Brown, 1960). Primates with localized lesions show retardation specifically associated with the site of the lesion; most interesting is that frontal lobe lesions are related to *inefficient response suppression* (Mishkin, Prockop, & Rosvold, 1962) and difficulties in overcoming object preferences (Brush, et al., 1961). As frontal lobe lesions are not easily diagnosed without exhaustive medical examinations, and as the aged Ss in our study exhibited just these behaviors in their learning, organicity as a factor cannot be ruled out.

(b) Gradient of experience and education. It can be shown in monkeys that prior experience with the stimulus objects facilitates the acquisition of learning set (Cross, Fletcher, & Harlow, 1963; Riopelle, Cronholm, & Addison, 1962). The slowing in the performance of the aged groups in the present study could not be attributed to a differential lack of experience with the

stimulus cues, but there may be some relation to a deficit in the type of experience necessary for the efficient acquisition of observing skills and the suppression of incorrect strategies with educational attainment. Educational attainment would obviously contribute to differences among the preschool, fifth-grade, and college groups, but could also have contributed to the inferiority of the aged group. All but one of the samples of the aged $\$s$ were deficient in formal education; the sample from the professional group did possess considerable educational achievement, and their more efficient formation of learning set may be related to their educational attainment. While years of formal education is probably not directly related to the efficiency of learning set formation, it is associated with experience on tasks that are similar to the learning set task, or related to it in such a way that transfer enhances performance (see Spiker, 1963).

(c) Adequacy of environmental stimulation. There is little doubt that an enriched environment is an important variable in developing and maintaining cognitive abilities. The learning-set performance of laboratory (cage-reared) monkeys is inferior to monkeys that have received intensive domestic care (Rumbaugh & Prim, 1964), and to those reared in the wild (Levinson, unpublished observation). Social deprivation, especially that associated with institutionalization, interferes with the performance of retarded children on cognitive tasks (e.g. Stevenson & Zigler, 1957; Zigler, 1962; Zigler & Williams, 1963), and culturally disadvantaged children from underprivileged environments fall significantly below the national average on cognitive measures which are ostensibly "culture fair" (Havighurst, 1963). Although the learning set performance of the aged group from one of the institutions sampled was comparable with that of the sample which dwelt at home and attended the Day Center, the sample from the institution with the most impoverished environment produced the slowest learners and the highest proportion of $\$s$ who failed to achieve learning

set (Chapter 6). Maintenance of the older individual in a stimulating environment slows deterioration, and the introduction of an active work program into an institution is said to reverse deterioration in some Ss (personal communication to Dr. Levinson from members of the institution staff).

(d) Intelligence. Learning-set formation in children is related to both MA and IQ (Ellis, 1958; Girardeau, 1959; Harter, 1964; Kaufman & Peterson, 1958; Koch & Meyer, 1959; Stevenson & Swartz, 1958; Wischner & Hall, 1962). Wischner and Hall (1962), in a developmental study of learning set in normal school children from kindergarten through the sixth grade, found little difference in performance of children with MA from 5 to 9 years, but a sharp break occurred at MA 9 so that children with MA from 9 to 13 years were significantly better in learning set performance. The difference we found between the performances of the preschool and fifth-grade groups fits in with this finding.

(e) Attention. The age differences in learning set formation seem to be partly attributable to age differences in distractibility. Failure to attend closely to the task would result in a lack of sensitivity to the reward contingencies, and failure to attend to the relevant object cues would result in an increase in position responses. The relative inattentiveness of young children is well known (several investigators have also noted that mentally retarded Ss are highly distractible (Girardeau, 1959; House & Zeaman, 1961; Martin & Blum, 1961; Stevenson & Swartz, 1958; Zeaman, 1959)), and that position responses are a more important source of error in these Ss than in normal Ss (Reese, 1963)]. Fluctuations of attention in the aged in the present study were apparent in non-task oriented responses such as attempted socialization and irrelevant conversation, and in task oriented behavior (e.g. S spontaneously remarks that he has forgotten which object was rewarded on previous trials).

Distractability has been related to an attenuation of the stimulus trace in brain-damaged monkeys forced to delay between trials of discrimination learning

set problems (Riopelle, et al., 1953), and may reflect cognitive deterioration in the aged. Failure on early sessions in the latter may mobilize factors of inattention and reactive inhibition which interfere with performance.

Zeaman & House (1963) in describing the learning in retardates of a single discrimination problem, published a series of homogeneous curves similar in form to those derived from learning set data in the present study. The final rates of homogeneous groups were shown to be similar with differences between them occurring only in the duration of initial poor performance; once improvement started, there was a rapid rise to asymptotic level. Zeaman & House have suggested a two-process view: the initial random performance is controlled by an attention process while the sharply rising section of the curve is indicative of instrumental discrimination learning. They suggest that the early poor performance reflects a failure to attend to the relevant cues and the duration of random performance is determined by stimulus factors, such as number and nature of the cues employed, and transfer operations. Transfer operations include training on an easy discrimination problem prior to a difficult one, overlearning and forcing S's attention to the relevant cues. Attention at the moment of choice is limited to one, or a few, of the possible stimulus dimensions available to the S; S may learn to attend to stimulus aspects as a result of differential reinforcement; and cues for instrumental learning are those aspects of the stimulus which are attended to.

The attention aspect of the Zeaman theory is similar to an explanation proposed by Levinson (1958) for the acquisition of a type of learning set, two-position oddity, which was viewed as a special case of discrimination learning. Manipulations which forced observing responses to the significant cue aspects speeded the development of such a learning set in monkeys (see also Peterson & Rumbaugh, 1963). In a recent experiment exploring attentional processes in discrimination, White and Plum (in press) photographed children's

eye movements. They found maximal scanning at the onset of solution within a problem and at the onset of learning set formation. A high correlation between the number of scanning responses and the efficiency of learning set formation suggested that superior discrimination learning was associated with more scanning of the stimuli. Kluver (1933) found a similar relation between comparison behavior and discrimination learning efficiency in monkeys.

The implication is that factors which increase attention to the relevant cues should speed learning in the immature organism, in the CNS damaged organism (retarded, brain damaged, and those with special sensory defects), and in the aged. Elimination of distracting details and backgrounds, increased spatial contiguity of cue and incentive should strengthen the memory trace and facilitate the acquisition of discrimination learning set. Zeaman and House (1963) have proposed similar techniques for the training of retardates.

(f) Age-related motivational changes. It has been found difficult to motivate older Js in animal studies, as these Js have a decreased activity level and are not as strongly motivated as younger Js by a given deprivation level or incentive. These problems are also encountered in the aged human Js, with the additional complication of social demands.

At the preschool age, children's motivation is easily enlisted by preliminary "getting-acquainted" sessions, by attractive test materials, and by group participation. The fifth-grade groups and the college Js in our study displayed good motivation, as well as could be judged, and interest in the test per se was an important source of motivation. For most of the aged Js, an appeal to contribute to a research project by participation as a subject appeared effective as a starting point, but the older J presented a special motivational problem in that the food incentive could not be used and a monetary reward had to be introduced. The group pressures were strong factors in

getting the aged ss to work, but did not determine the quality of the work.

The test experience was prolonged over many more sessions in the aged groups than in any of the other groups, and although it is impossible to determine whether the prolongation of the sessions was a function of poor motivation or of reduced learning ability, it introduced the possibility of boredom, and there is no doubt that anxiety, concomitant with an awareness of lessening learning efficiency, slowed the learning process. The older ss appeared more prone than the younger ss to worry about errors, because of an overemphasis on accuracy and concern about making fools of themselves.

Chapter 9

Summary

A "learning set" is acquired through practice on problems that have a common basis of solution, and has been formed when the common solution has been learned. The most widely studied learning set, "object-quality discrimination learning set," has been investigated in human and, even more extensively, infra-human subjects (§s), but the processes underlying the formation of this learning set are not yet thoroughly understood. The present study investigated the acquisition of object-quality discrimination learning set at four age levels: early childhood, middle childhood, early adulthood, and old age. The study was unique in that it was (a) the first to compare learning set formation over such a wide age range, (b) the first report of learning set formation in the aged, and (c) the first study to apply and compare the efficacy of three methods of analyzing systematic response patterns (the Harlow error factor analysis, the Levine H-model, and Bowman's modification of the H-model, which are described in detail in the report).

The purposes of the study were (a) to search for systematic response patterns occurring in the course of learning set formation and (b) to examine age differences in the efficiency of learning set formation. Although the primary focus of the study was on the process of learning set formation, the learning set task provided a unique opportunity to examine developmental processes, since it can be applied with equal validity over the wide age range studied.

The §s were 53 nursery school children, 53 fifth-graders, 57 college freshmen, and 209 aged people ranging from 61 to 97 years of age. Each § was given practice on numerous two-stimulus simultaneous discrimination problems, using a different pair of stimuli in each problem. In each problem one stimulus was correct, the position of the correct stimulus was shifted from left to right in a randomly determined order, and each response to the correct

stimulus was rewarded. Four trials were given on each problem. After the four trials had been given on one problem, a new pair of stimulus objects was introduced, initiating a new problem, and the fixed number of trials was given on the new problem. The task of the subject was to learn the common basis of solution of the problems, so that a new problem could be solved on the basis of information gained on the first trial of the problem. The common solution was to continue to select the stimulus object chosen on trial one if the choice was correct, and to shift to the other stimulus object if the first-trial choice was incorrect. Training continued to a criterion of 93% correct choices on trials two through four of five consecutive problems, or until a predetermined fixed number of problems had been given. For the data analyses the 3s were divided into homogeneous groups on the basis of the number of problems required to attain the criterion.

Two kinds of data analysis were used. First, the acquisition curves were examined, considering only the percentage correct responses in blocks of problems; and second, a search was made for systematic patterns of responses, using the Harlow, Levine, and Roman methods of analysis.

Preschool Children. The speed of learning set formation and variation of age within the preschool range were not related. The learning set acquisition curves of the homogeneous groups possessed two phases and differed markedly from the learning curves resulting from mean-performance data (for the group as a whole). Performance showed a gradual improvement in Phase I, and rapid improvement in Phase II. The homogeneous groups differed primarily in the duration of Phase I.

An application of Harlow's method of error factor analysis indicated that stimulus preferences were infrequent, and constituted an unimportant source of error in the preschool children. "Response shift" and position habits were important sources of error, particularly in the slower learning groups. (The

"response shift" error is a greater frequency of errors following an initial correct response than following an initial error, and has been assumed to reflect a tendency to try out all stimuli in the discrimination problem.) The demonstration of the response shift error in preschool children is of theoretical importance, as it calls into question a basic assumption of Levine's method of analyzing systematic response patterns.

Application of Levine's method of analysis and Bowman's modification of it proved to be valuable. It was found that the problem solution was acquired piecemeal: the Lose-shift-object strategy ("shift object choice after an error") was acquired earlier in training than the Win-stay-object strategy ("perseverate object choice after a correct response"), and the Lose-shift-object strategy was frequently combined with the Win-stay-position strategy in Phase I. The difference in rate of acquisition of the two strategies comprising the problem solution (Win-stay-object, Lose-shift-object) may explain the two-phase appearance of the acquisition curves of the homogeneous groups, and the combination of the correct Lose strategy with a Win-position strategy accounts for the better than chance level of performance attained in Phase I.

The homogeneous groups differed in the speed of acquisition of the Win-stay-object strategy more than the Lose-shift-object strategy; and they also differed in the number of strategies used, and in the duration of the incorrect strategies. An orderliness in the elimination of incorrect strategies was found when the homogeneous groups were compared.

The Levine and Bowman analyses confirmed the identification of strong position response patterns in the error factor analysis, but clearly provided much additional information not available from the error factor analysis.

Further research is needed to determine in what ways the homogeneous groups differ, to account for the differences exhibited by the groups in their strategy behavior.

Fifth-Grade Children. The speed of learning set formation was not related to variations in IQ in the fifth-grade sample. In general, the acquisition curves of the homogeneous groups appeared to involve two phases, and to differ primarily in the duration of the first phase. Phase I was characterized by slow improvement in performance, and Phase II by rapid improvement.

Application of the Levine and Bowman methods of analysis indicated that hypotheses rather than the smaller strategy units controlled responses (an "hypothesis" consists of a Win strategy and a Lose strategy), but the Lose-shift object strategy was acquired earlier than the Win-stay-object strategy and the improvement of performance in Phase I suggests that Lose-shift-object may have been combined at some time with a Win-position strategy. Object hypotheses were dominant over position hypotheses in all of the homogeneous fifth-grade groups, but weak position hypotheses occurred, and appeared to influence the rate of acquisition of the learning set. The homogeneous groups differed in the number of incorrect hypotheses exhibited.

College Freshmen. The learning set acquisition curves of the homogeneous college groups were saltatory, with a pre-solution phase in which performance did not improve, followed by a rapid rise to criterion. The curves of the homogeneous groups differed primarily in the duration of Phase I. Analysis of strategies and hypotheses indicated that hypotheses rather than the smaller strategy units controlled behavior. Object hypotheses were dominant over position hypotheses in all groups, but weak position hypotheses were also evidenced in the slower learning groups. The homogeneous groups differed in the number of incorrect hypotheses exhibited, and in the slower learning groups Lose-shift-object developed earlier than Win-stay-object.

Aged Samples. The rate of acquisition of learning set was not related to age variations within the aged group. The group as a whole was exceedingly inefficient in developing learning set, but there were differences among the

samples. A sample of retired professionals was superior to the other aged samples, and a sample from one institution was inferior to the others. A Day-Center group did not differ from a sample from a second institution.

When the samples were combined and redistributed into homogeneous groups on the basis of learning rate, it was found that the learning set acquisition curves of the homogeneous groups exhibited two phases, with a prolonged initial phase in which performance rose above the chance level only toward the end of the phase, and a second phase of rapid improvement in performance. The homogeneous groups differed primarily in the duration of the first phase.

Responses were controlled primarily by hypotheses rather than the smaller strategy units. Lose-shift-object and Win-stay-object appeared to develop at the same rate. Position hypotheses were strong and predominated through long periods of training, but weak object hypotheses were also found. One of the especially prominent position hypotheses consisted of the Win-stay-position and Lose-shift-position strategies, indicating that the *Js* were sensitive to reward contingencies but were responding to irrelevant cues. The homogeneous groups differed in the variety and persistence of incorrect hypotheses.

Although age variations appeared to be irrelevant, comparison of the samples suggested that educational attainment and adequacy of everyday environmental stimulation are important determinants of learning efficiency in old age. The worst group came from an institution that seemed to provide inadequate stimulation and the best group was the best educated. Motivation was difficult to maintain in all of the samples.

Comparisons of analyses of individual *Js* with the analysis of the homogeneous group they comprised revealed that the group data partially misrepresented the individual data, indicating a need for a more valid method of obtaining homogeneous groups. The basic problem in analyzing individual data is that large numbers of problems must be blocked together, obscuring the occur-

rence of response patterns of short duration. (We used 10-problem blocks for most of the group analyses, and 50-problem blocks for individual analyses.)

Comparisons across Age Levels. A strong age trend in rate of learning set acquisition was obtained. The median numbers of problems required to attain the criterion were 20.4 for the preschool group, 10.8 for the fifth-graders, 6.7 for the college group, and about 120 for the combined aged groups. The retired professionals were somewhat inferior to the college and fifth-grade groups, but markedly superior to the other aged groups and the preschool group. (The validity of the comparison is questionable, because the retired professional sample was small.)

The shape of the learning set acquisition curve was essentially the same at every age level, exhibiting an initial phase of slow improvement (except in the fastest learning groups, in which there was no improvement in Phase I), and a second phase of rapid improvement.

Responses were controlled primarily by hypotheses in all but the preschool group, and by the smaller strategy units in the preschool group. Position habits were strong in the preschool group, and even stronger in the aged, but were weak in the fifth-grade and college groups. The variety and persistence of incorrect response patterns seemed to be greater in the youngest and oldest groups than in the others, and greater in the oldest than in the youngest group.

A nonreward seemed to provide more information than a reward in all but the aged group, since in all but the aged group Lose-shift-object developed earlier than Win-stay-object.

Conclusions. Learning set formation consists of eliminating incorrect response patterns. The chance level of performance in Phase I of the acquisition curve reflects dominance of incorrect strategies. The rise in performance in Phase I occurs when Lose-shift-object is combined with a Win-position

strategy, and the transition to Phase II occurs as Win-stay-object replaces the Win-position strategy. In the fastest learning Ss, Lose-shift-object is never combined with a Win-position strategy, but an incorrect position or object hypothesis is replaced immediately by the correct object hypothesis in the transition to Phase II.

Age differences in the duration of Phase I reflect age differences in the number of different response patterns exhibited and in the duration of the incorrect response patterns.

The deficiency in learning rate in the aged is not a result of their slow reaction time because the task is self-paced. The relation between age and speed of learning set formation seems to reflect the relation between age and variations in the variety and persistence of incorrect response patterns. The variables which might account for the latter relation include: (a) developmental changes in cognitive abilities, (b) gradients of experience with similar or related tasks, and of educational attainment, (c) variations in adequacy of environmental stimulation, (d) intellectual differences, (e) developmental changes in attentional processes, and (f) age-related motivational changes. These variables were discussed at some length in the report.

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Appendix A

The Harlow, Levine, and Bowman Methods of Data Analysis

Harlow (1949, 1950, 1959) observed and described a number of systematic response patterns producing errors in object-quality discrimination learning problems, and termed these patterns "error factors." He developed methods for assessing the strength or importance of each of the error factors in the animal's performance, but emphasized that the error factor analysis was empirical, serving only to reduce the data by describing what seemed to be the more important aspects of the animal's behavior. The H-model developed by Levine (1959, 1963) was designed to incorporate the error factors, and also included the correct response pattern leading to problem solution. The H-model introduced new, previously unidentified response patterns, which were included to balance the system mathematically, but it also introduced new definitions of some of the error factors, and the H-model and error factor analyses do not yield identical results. Bowman (1963) modified the Levine model to permit separate analyses of the behavior following an error and following a correct response.

Bowman's Model

Bowman's (1963) model requires that the response on Trial 1 of a problem is correct and rewarded ("win") or incorrect and nonrewarded ("lose"); the model cannot deal with partial reinforcement unless additional assumptions are made. Bowman assumes that the responses on Trials 1 and 2 are both to an object or both to a position; the response cannot shift from an object on Trial 1 to a position on Trial 2 (or vice versa). The response on Trial 2, therefore, must be to the same object or position as on Trial 1 ("stay") or to the other object or position ("shift"). All possible responses on Trial 2, given these

conditions, can be designated by a set of eight labels, as indicated in Table A-1. These labels are, of course, descriptive.

The eight kinds of Trial-2 response are called "strategies,"¹ and can be represented in two matrices, a "win" matrix and a "lose" matrix, as shown in Table A-2. The frequencies (n) of Trial-2 responses in each of the eight cells of these matrices are obtained by tabulating the raw data, and these frequencies can be converted into proportions, as shown in Table A-3.

Bowman's equations permit the calculation of the probabilities of the strategies shown in Tables A-1 and A-2, using the proportions in Table A-3. The equations for win and lose strategies are exactly analogous, however, and the presentation of the equations can therefore be simplified by dealing with a general case in which the letters W and L have been dropped from the designations of the strategies. Table A-4 gives the matrix for the general case. (The specific working equations for each of the strategies are given in Table A-5.)

¹Both Bowman and Levine (personal communications) strongly object to our labeling these units "strategies", because the term has so many other meanings.

Table A-1
The Eight Strategies in Bowman's Model

First-Trial Outcome	Response on Trial 2 to	Label	Symbol
Win	Same object as on Trial 1	Win Stay on Object	WSt _o
Win	Other object	Win Shift Object	WSh _o
Win	Same position as on Trial 1	Win Stay on Position	WSt _p
Win	Other position	Win Shift Position	WSh _p
Lose	Same object as on Trial 1	Lose Stay on Object	LSt _o
Lose	Other object	Lose Shift Object	LSh _o
Lose	Same position as on Trial 1	Lose Stay on Position	LSt _p
Lose	Other position	Lose Shift Position	LSh _p

Table A-2
The Eight Strategies in Bowman's Model Represented in Matrices

		Object Chosen on Trials 1 & 2			
		Same	Different	Same	Different
Position Occupied by Correct Object on Trials 1 & 2	LL or RR	WSt _o or WSt _p	WSh _o or WSh _p	LSt _o or LSt _p	LSh _o or LSh _p
	LR or RL	WSt _o or WSh _p	WSh _o or WSt _p	LSt _o or LSh _p	LSh _o or LSt _p
		WIN MATRIX		LOSE MATRIX	

Note: "L" = Left; "R" = Right.

Table A-3

Symbolic Representation of the Proportion of Responses in Each Cell of the Matrices of Table A-2

Object Chosen on Trials 1 & 2

		Object Chosen on Trials 1 & 2			
		Same	Different	Same	Different
Position Occupied by Correct Object on Trials 1 & 2	LL or RR	$P_{11} = \frac{n_{11}}{n_{11}+n_{12}}$	$P_{12} = \frac{n_{12}}{n_{11}+n_{12}}$	$P_{13} = \frac{n_{13}}{n_{13}+n_{14}}$	$P_{14} = \frac{n_{14}}{n_{13}+n_{14}}$
	LR or RL	$P_{21} = \frac{n_{21}}{n_{21}+n_{22}}$	$P_{22} = \frac{n_{22}}{n_{21}+n_{22}}$	$P_{23} = \frac{n_{23}}{n_{23}+n_{24}}$	$P_{24} = \frac{n_{24}}{n_{23}+n_{24}}$
		WIN MATRIX		LOSE MATRIX	

Note: n_{ij} is the frequency of responses tabulated in cell ij . E.g. n_{11} (in the win matrix) is the number of correct responses on Trial 2 when the Trial 1 response was also correct and the position of the correct object was not changed from Trial 1 to Trial 2. Correspondingly, n_{13} (in the lose matrix) is the number of errors on Trial 2 when the Trial 1 response was an error and the position of the correct response was unchanged.

Table A-4

The General Case of Bowman's Model

Object Chosen on Trials 1 & 2

Position Occupied by Correct Object on Trials 1 & 2	STRATEGIES		PROPORTIONS	
	Same	Different	Same	Different
LL or RR	St_o or St_p	Sh_o or Sh_p	x	1 - x
LR or RL	St_o or Sh_p	Sh_o or St_p	y	1 - y

It can be seen from examination of Table A-4 that:

$$p(St_o) + p(St_p) + p(Sh_o) + p(Sh_p) = 1 \quad (\text{Equation 1})$$

since St_o and St_p are both in the upper left cell in Table A-4,

$$p(St_o) + p(St_p) = x$$

and similarly

$$p(Sh_o) + p(Sh_p) = 1-x.$$

It can be proved that:

$$p(St_o) - p(Sh_o) = x + y - 1 \quad (\text{Equation 2})$$

which can also be written

$$p(St_o) - p(Sh_o) = x - (1 - y).$$

Proof:

Since:

$$[p(St_p) - p(St_p)] = 0$$

$$[p(St_o) - p(St_o)] = 0$$

$$[p(Sh_p) - p(Sh_p)] = 0$$

and $p(St_o) - p(Sh_o) = p(St_o) - p(Sh_o) + 0$,

$$\begin{aligned} p(St_o) - p(Sh_o) &= p(St_o) - p(Sh_o) + [p(St_p) - p(St_p)] + [p(St_o) - p(St_o)] \\ &\quad + [p(Sh_p) - p(Sh_p)] \end{aligned}$$

Rearranging terms:

$$\begin{aligned} p(St_o) - p(Sh_o) &= p(St_o) + p(St_p) + p(St_o) + p(Sh_p) - \\ &\quad [p(St_o) + p(St_p) + p(Sh_o) + p(Sh_p)] \end{aligned}$$

But:

$$p(St_o) + p(St_p) = x$$

and

$$p(St_o) + p(Sh_p) = y$$

(from Table A-4), and the sum of the bracketed terms equals 1 (from Equation 1).

Therefore:

$$p(\text{St}_0) - p(\text{Sh}_0) = x + y - 1.$$

Similarly, it can be proved that:

$$p(\text{St}_p) - p(\text{Sh}_p) = x - y \quad (\text{Equation 3})$$

The proofs require the assumption that the probability of a strategy is the same when the position of the correct object changes from Trial 1 to Trial 2 (LR and RL problems) as when it remains unchanged (LL and RR problems).

Interval Estimates. An interval estimate of the probability of each strategy can be computed, based on Equations 2 and 3. The limits depend on the relations between the stay and shift strategies. For example, if

$$p(\text{St}_0) - p(\text{Sh}_0) > 0 \text{ and } p(\text{St}_p) - p(\text{Sh}_p) > 0,$$

both $p(\text{St}_0)$ and $p(\text{St}_p)$ must be greater than zero, but $p(\text{Sh}_0)$ and $p(\text{Sh}_p)$ have lower limits of zero. The upper limit of $p(\text{Sh}_0)$ and $p(\text{Sh}_p)$ can be seen in Table A-4, in the cell which contains these two terms, the $1 - x$ cell. From this cell if $p(\text{Sh}_0) = 0$, then $p(\text{Sh}_p) = 1 - x$. Conversely, if $p(\text{Sh}_p) = 0$, then $p(\text{Sh}_0) = 1 - x$. Therefore, the limits of these two terms are 0 and $1 - x$. Or symbolically:

$$(a) \quad 0 \leq p(\text{Sh}_0) \leq 1 - x$$

$$(b) \quad 0 \leq p(\text{Sh}_p) \leq 1 - x.$$

Substituting these limits in Equations 2 and 3:

$$(c) \quad x + y - 1 \leq p(\text{St}_0) \leq y$$

$$(d) \quad x - y \leq p(\text{St}_p) \leq 1 - y.$$

Table A-5 presents the working equations for computing the upper and lower limits of each win and lose strategy, for all possible relations between the stay and shift strategies.

Table A-5

Lower & Upper Limits, Respectively, of the Strategies in Bowman's Model

Win Matrix ^a	WSt _o	WSh _o	WSt _p	WSh _p
I A > 0, B > 0	P ₁₁ -P ₂₂ ; P ₂₁	0; P ₁₂	P ₁₁ -P ₂₁ ; P ₂₂	0; P ₁₂
II A < 0, B > 0	0; P ₂₁	P ₁₂ -P ₂₁ ; P ₁₂	P ₁₁ -P ₂₁ ; P ₁₁	0; P ₂₁
III A > 0, B < 0	P ₁₁ -P ₂₂ ; P ₁₁	0; P ₂₂	0; P ₂₂	P ₂₁ -P ₁₁ ; P ₁₂
IV A < 0, B < 0	0; P ₁₁	P ₂₂ -P ₁₁ ; P ₂₂	0; P ₁₁	P ₂₁ -P ₁₁ ; P ₂₁
Lose Matrix ^b	LSt _o	LSh _o	LSt _p	LSh _p
V C > 0, D > 0	P ₁₃ -P ₂₄ ; P ₂₃	0; P ₁₄	P ₁₃ -P ₂₃ ; P ₂₄	0; P ₁₄
VI C < 0, D > 0	0; P ₂₃	P ₁₄ -P ₂₃ ; P ₁₄	P ₁₃ -P ₂₃ ; P ₁₃	0; P ₂₃
VII C > 0, D < 0	P ₁₃ -P ₂₄ ; P ₁₃	0; P ₂₄	0; P ₂₄	P ₂₃ -P ₁₃ ; P ₁₄
VIII C < 0, D < 0	0; P ₁₃	P ₂₄ -P ₁₃ ; P ₂₄	0; P ₁₃	P ₂₃ -P ₁₃ ; P ₂₃

$$^aA = p(WSt_o) - p(WSh_o) = P_{11} - P_{22}$$

$$B = p(WSt_p) - p(WSh_p) = P_{11} - P_{21}$$

$$^bC = p(LSt_o) - p(LSh_o) = P_{13} - P_{24}$$

$$D = p(LSt_p) - p(LSh_p) = P_{13} - P_{23}$$

Note: The following are included in Case I: A = 0, B > 0; A > 0, B = 0; and A = 0, B = 0; in Case IV: A = 0, B < 0; A < 0, B = 0; in Case V: C = 0, D > 0; C > 0, D = 0; C = 0, D = 0; in case VIII: C = 0, D < 0; C < 0, D = 0.

Equations 2 and 3 can be used to estimate the difference between the probabilities of complementary strategies. The same result can be obtained by finding the difference between the upper limits (or lower limits) of the two strategies. For example, if

$$p(\text{St}_o) - p(\text{Sh}_o) > 0 \text{ and } p(\text{St}_p) - p(\text{Sh}_p) > 0,$$

the difference between the upper limits of the two object strategies is:

$$\begin{aligned} p(\text{St}_o) - p(\text{Sh}_o) &= y - (1 - x) = y - 1 + x \\ &= x + y - 1 \end{aligned}$$

which is the same as Equation 2. Equations 2 and 3 can be used to transform the range estimates into differential scores, a procedure that considerably simplifies the data presentation but with some loss of information. A positive value would indicate that $p(\text{St}_o) > p(\text{Sh}_o)$ and a negative value would indicate the reverse.

Levine's Model

Levine (1963) presents a complete, rather complex derivation of the equations, but has shown elsewhere (personal communication) that the relation between his equations and Bowman's is such that either set can be derived from the other. In order to present the simplest possible form, the following material is presented in terms of the Bowman model.

Levine (1963) outlines a mediation theory explaining the occurrence of the response patterns identified by his method of data analysis; Bowman makes no theoretical assumptions, presenting his model only as a method of data analysis.

The number of responses representing any given response pattern (such as H_1 , WSt_o & LSh_o) relative to the total number of responses is equal to the number of such responses following a win (e.g. the number of responses designated as WSt_o) plus the number of such responses following a loss (e.g. LSh_o responses), divided by the total number of responses. Symbolically,

using H_1 as an example:

$$p(H_1) = \frac{f_{WSt_0} + f_{LSh_0}}{N_W + N_L}$$

where $p(H_1)$ is the probability of H_1

f_{WSt_0} is the frequency of WSt_0 responses

f_{LSh_0} is the frequency of LSh_0 responses

N_W is the number of wins

N_L is the number of losses.

By definition:

$$p(WSt_0) = \frac{f_{WSt_0}}{N_W}$$

and

$$p(LSh_0) = \frac{f_{LSh_0}}{N_L}$$

Therefore:

$$p(H_1) = \frac{p(WSt_0)(N_W) + p(LSh_0)(N_L)}{N_W + N_L}$$

Levine assumes that $N_W = N_L$. Therefore:

$$p(H_1) = \frac{p(WSt_0) + p(LSh_0)}{2}$$

In general, the probability of any H is $1/2$ the sum of the probabilities of the strategies comprising the H. In Levine's system the Hs are paired (see Table 1-1, p. 7), and equations are derived for calculating the difference between the probabilities of the Hs in each pair. These equations are given in Table A-6. An example of the derivation of these equations is given below, in terms of Bowman's model, which yields a simple derivation. The notations of Tables A-2 and A-3 are used.

Example. It is to be proved that $D_a = 1/2(P_{11} + P_{21} + P_{14} + P_{24} - 2)$ ¹
 By definition, $D_a = p(H_1) - p(H_2)$. Therefore:

$$\begin{aligned} D_a &= 1/2 [p(WSt_0) + p(LSh_0)] - 1/2 [p(WSh_0) + p(LSt_0)] \\ &= 1/2 [p(WSt_0) + p(LSh_0) - p(WSh_0) - p(LSt_0)] \\ &= 1/2 \{ [p(WSt_0) - p(WSh_0)] - [p(LSt_0) - p(LSh_0)] \} \\ &= 1/2 [(P_{11} - P_{22}) - (P_{13} - P_{24})] \quad (\text{from Table A-5}) \end{aligned}$$

But since $P_{22} = 1 - P_{21}$ and $P_{13} = 1 - P_{14}$ (from Table A-3),

$$\begin{aligned} D_a &= 1/2 [(P_{11} - 1 + P_{21}) - (1 - P_{14} - P_{24})] \\ &= 1/2 (P_{11} + P_{21} - 1 - 1 + P_{14} + P_{24}) \\ &= 1/2 (P_{11} + P_{21} + P_{14} + P_{24} - 2). \end{aligned}$$

Levine assumes that $p(WSh_0) = p(LSh_0)$. Although this assumption is not required for the derivation given here, it should be noted that if these probabilities are not equal, Bowman's method of analysis detects this inequality, but Levine's can detect it only indirectly.

Levine assumes that $N_W = N_L$, but equations can be derived from Bowman's model for the case in which this assumption is not satisfied. For example, again using D_a :

$$D_a = p(H_1) - p(H_2).$$

¹ See Table A-6.

$$= \frac{1}{N_W + N_L} \left\{ \left[p(\text{WSt}_0) (N_W) + p(\text{LSh}_0) (N_L) \right] - \left[p(\text{WSh}_0) (N_W) + p(\text{LSt}_0) (N_L) \right] \right\}$$

$$= \frac{1}{N_W + N_L} \left\{ (N_W) \left[p(\text{WSt}_0) - p(\text{WSh}_0) \right] - (N_L) \left[p(\text{LSt}_0) - p(\text{LSh}_0) \right] \right\}$$

$$= \frac{1}{N_W + N_L} \left[(N_W) (p_{11} + p_{21} - 1) - (N_L) (p_{13} + p_{23} - 1) \right]$$

$$= \frac{1}{N_W + N_L} \left[(N_W) (p_{11} + p_{21}) - N_W - (N_L) (p_{13} + p_{23}) + N_L \right]$$

$$= \frac{1}{N_W + N_L} \left[(N_W) (p_{11} + p_{21}) - N_W - (N_L) (1 - p_{14} + 1 - p_{24}) + N_L \right]$$

$$= \frac{1}{N_W + N_L} \left[(N_W) (p_{11} + p_{21}) - N_W - 2(N_L) + (N_L) (p_{14} + p_{24}) + N_L \right]$$

$$= \frac{1}{N_W + N_L} \left[(N_W) (p_{11} + p_{21}) + (N_L) (p_{14} + p_{24}) - (N_W + N_L) \right]$$

The equation is unwieldy, but can be applied if the experimental procedure requires it.

Table A-6

Differential Solutions for Paired Hypotheses in Levine's Model

Hypotheses	Differential Solutions
$D_a = p(H_1) - p(H_2)$	$1/2 (P_{11} + P_{14} + P_{21} + P_{24} - 2)$
$D_b = p(H_3) - p(H_4)$	$1/2 (P_{11} + P_{14} + P_{22} + P_{23} - 2)$
$D_x = p(H_5) - p(H_6)$	$1/2 (P_{11} + P_{13} + P_{21} + P_{23} - 2)$
$D_y = p(H_7) - p(H_8)$	$1/2 (P_{11} + P_{13} + P_{22} + P_{24} - 2)$

Note: See Table 1-1 for definitions of each of the H s; the p 's are obtained from Table A-3.

Barlow (1976) suggests that the theoretical hypothesis should be based on performance following only an initial error, since the observed frequency of consecutive errors is based on performance following only an initial error.

Considering only the first two trials, Barlow deals only with the last-act strategy, and does not calculate the probability in the same way as Brown, since Barlow obtains a point estimate and Brown obtains an interval estimate of estimate relative to the last-act strategy.

Position Habit. Position habit errors are measured by counting the number of responses at the left and right positions as correct or incorrect to one position indicated a position preference. This error factor is not necessarily the same as Levine's (1963) position preference, which is defined as a tendency to repeat the same position on Trials 1 and 2. For example, if p is usually

Harlow's Error Factors

Stimulus Perseveration. Stimulus perseveration (stimulus preference) was defined as the excess of consecutive errors following an error on Trial 1, beyond those which would be predicted from the obtained frequency of errors. The predicted or theoretical proportion of consecutive errors through any given trial is computed for that trial by taking the product of the obtained proportions of errors on that trial and each preceding trial. For example, the theoretical proportion of consecutive errors through Trial 3 would be the proportion of errors obtained on Trial 1, times the proportion of errors obtained on Trial 2, times the proportion of errors obtained on Trial 3. (These obtained proportions are obtained for a group of subjects performing on a given trial in a block of problems.) The theoretical number of consecutive errors through a given trial is the theoretical proportion of consecutive errors (calculated as indicated above) times the total number of responses of all subjects on all problems through that trial.

Harlow (1950) suggested that the theoretical proportion should be based on performance following only an initial error, since the obtained frequency of consecutive errors is based on performance following only an initial error.

Considering only the first two trials, Harlow deals only with the Lose-stay-object strategy, and does not calculate its probability in the same way as Bowman, since Harlow obtains a point estimate and Bowman obtains an interval estimate or estimate relative to the Lose-shift-object strategy.

Position Habit. Position habit errors are measured by counting the number of responses to the left and right positions; an excess of responses to one position indicates a position preference. This error factor is not necessarily the same as Levine's (1963) position preference, which is defined as a tendency to repeat the same position on Trials 1 and 2. For example, if Ss usually

chose the left object on Trial 1 and followed the correct object on Trial 2, they would have a position preference as defined by Harlow, but not as defined by Levine. A position preference identical to that defined by Levine can be derived from Bowman's strategies, by combining WSt_p and LSt_p , but Bowman does not include this error factor in his formal model.

Differential Cue Error. The differential cue error is defined as a greater frequency of errors on problems on which the position of the rewarded object changes from Trial 1 to 2 ("differential cue" problems) than on problems on which the position of the rewarded object is unchanged ("Multiple cue" problems). The ratio of errors on differential cue problems to errors on multiple cue problems is the "comparable trial error ratio" (CTE ratio).

Since the object strategies are independent of position changes from Trial 1 to 2, the differential cue error results from position strategies. In Bowman's terms, the differential cue error occurs when WSt_p is greater than WSh_p (if LSh_p is equal to or greater than LSt_p) and when LSh_p is greater than LSt_p (if WSt_p is equal to or greater than WSh_p). In Levine's system, this error occurs when D_b is greater than zero ($WSt_p \& LSh_p > WSh_p \& LSt_p$). Bowman's model accounts for this error by either the win or lose strategy (or both), but Levine (personal communication) has shown that it is the same as H_3 ($WSt_p \& LSh_p$).

Response Shift. Response shift errors have been given several definitions. According to one definition, it is a greater frequency of errors on Trial 2 following a correct response on Trial 1 than following an error on Trial 1. A second definition describes response shift as a greater frequency of errors following a series of a given number of correct responses when the series includes Trial 1 (correct response on Trial 1) than when the series does not include Trial 1 (error on Trial 1). Still other definitions have been used, based on the assumption that response shift results from a "tendency to respond to both

stimuli in the object-discrimination learning situation" (Harlow, 1959, p. 516). The first kind of response shift is reflected in Bowman's model when LSh_0 is relatively stronger than WSt_0 . It can be represented in Levine's model by a combination of $D_a > 0$ and $D_x < 0$ (indicating $WSt_0 \& LSh_0 > WSh_0 \& LSt_0$, and $WSh_0 \& LSh_0 < WSt_0 \& LSt_0$). The other kinds of response shift cannot be represented by the two trial models of Bowman and Levine.

Positions of the objects are changed and the appropriate reward will be
 delivered while the screen separates the subjects from the subjects.

Subjects:

Problems:

Dates:

Trial	No.	Response	Trial	No.	Response
1	1		1	1	
2	2		2	2	
3	3		3	3	
4	4		4	4	
5	5		5	5	
6	6		6	6	
7	7		7	7	
8	8		8	8	
9	9		9	9	
10	10		10	10	
11	11		11	11	
12	12		12	12	
13	13		13	13	
14	14		14	14	
15	15		15	15	
16	16		16	16	
17	17		17	17	
18	18		18	18	
19	19		19	19	
20	20		20	20	

Appendix B

Sample Sheet for Daily Run of Ten Problems

The letters L and R indicate the position of the correct object. At the beginning of each four-trial block, a new pair of stimuli is introduced, initiating a new problem. A correct response is indicated by a plus in the blank space, and an error by a minus (or other appropriate symbols). The positions of the objects are changed and the appropriate reward-well is baited while the screen conceals the materials from the subject.

Subject:

Problems:

Date:

Trial	S+	Response	Trial	S+	Response
1	L	_____	21	L	_____
2	R	_____	22	L	_____
3	R	_____	23	R	_____
4	R	_____	24	L	_____
5	L	_____	25	R	_____
6	L	_____	26	L	_____
7	L	_____	27	R	_____
8	R	_____	28	R	_____
9	L	_____	29	L	_____
10	R	_____	30	R	_____
11	L	_____	31	L	_____
12	R	_____	32	L	_____
13	R	_____	33	R	_____
14	L	_____	34	R	_____
15	L	_____	35	L	_____
16	R	_____	36	R	_____
17	R	_____	37	L	_____
18	R	_____	38	R	_____
19	R	_____	39	R	_____
20	L	_____	40	L	_____

Appendix C

Sample Work Sheet for Bowman & Levine Analyses

Position
of correct
object

Responses on Trials 1 and 2

LL or
RRLR or
RL

	++	+-
LL or RR	n_{11}	n_{12}
LR or RL	n_{21}	n_{22}

WIN MATRIX

	--	-+
LL or RR	n_{13}	n_{14}
LR or RL	n_{23}	n_{24}

LOSE MATRIX

Note: n_{ij} corresponds to the frequencies depicted in Table A-3.